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Light-Duty Automotive Technology and Fuel Economy Trends Through 1999

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by

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Executive Summary

Introduction to the Report

This report is a summary of the key trends related to the fuel economy of model year 1975 through 1999 light vehicles sold in the United States.

The fuel economy values in this report are laboratory data similar to those used by the U.S. Department of Transportation (DOT) for compliance with the corporate average fuel economy standards. These laboratory values, however, are significantly higher than the estimated values used on new car labels and in the *Fuel Economy Guide*.

Light vehicles include those vehicles that U.S. EPA and DOT classify as cars or light-duty trucks (sport utility vehicles, minivans, and pickup trucks with less than 8,500 pounds gross vehicle weight ratings).

Importance of the Report

Since the early 1970s, the U.S. EPA has issued reports that summarize new light vehicle fuel economy data.

Fuel economy continues to be a major area of public and policy interest for several reasons, including:

(1) Fuel economy is directly related to carbon dioxide emissions, the most prevalent pollutant associated with global warming, and light vehicles contribute about 20 percent of all U.S. carbon dioxide emissions.

(2) Light vehicles account for approximately 40 percent of all U.S. oil consumption; crude oil, from which nearly all light vehicle fuels are made, is considered to be a finite natural resource.

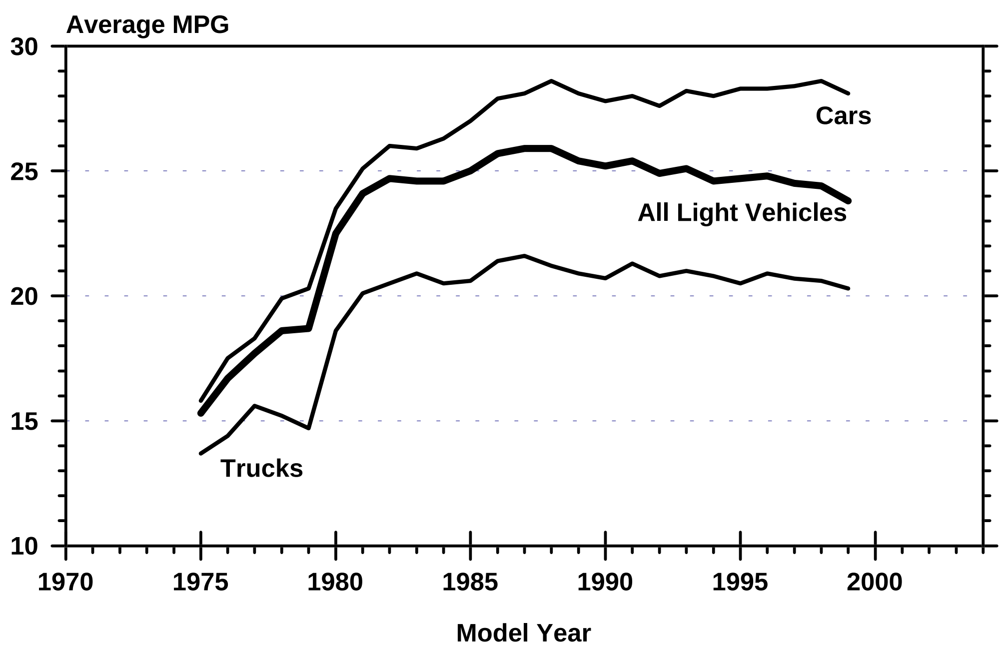
(3) Fuel economy is directly related to vehicle fueling cost.

Highlight #1: **Fuel Economy is Declining**

The average fuel economy for all model year 1999 light vehicles is 23.8 miles per gallon (MPG). Within the new light vehicle category for 1999, average fuel economy is 28.1 MPG for passenger cars and 20.3 MPG for light-duty trucks. The 1999 fuel economy average is the lowest value since 1980 and is 2.1 MPG less than the peak value of 25.9 MPG achieved in both 1987 and 1988. Average new light vehicle fuel economy has dropped 1.0 MPG since 1996.

All of the fleet-wide improvement in new light vehicle fuel economy occurred from the middle 1970s through the late 1980s, but it has been consistently falling since the late 1980s. Viewed separately, the average fuel economy for new cars has been essentially flat over the last 14 years, varying only from 27.6 MPG to 28.6 MPG. Similarly, the average fuel economy for new light trucks has been largely unchanged for the past 19 years, ranging from 20.1 MPG to 21.6 MPG. The increasing market share of light-duty trucks, which have lower average fuel economy than cars, is the primary reason for the decline in fuel economy of the overall new light vehicle fleet.

MPG by Model Year

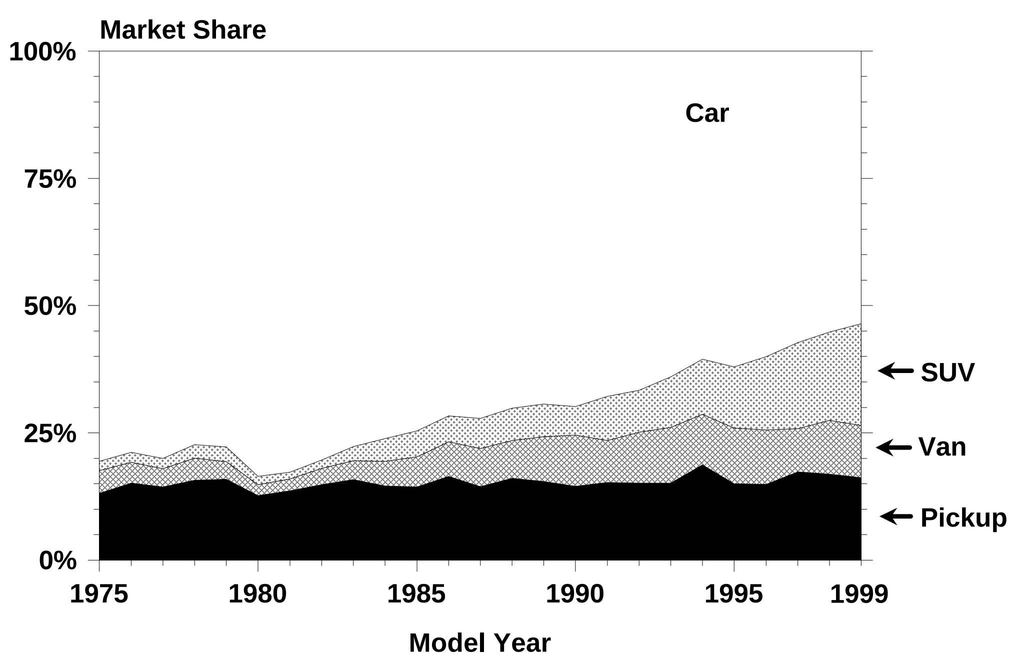


<u>Highlight #2</u>: <u>Truck Sales Continue to Increase</u>

Sales of light-duty trucks, which include sport utility vehicles (SUVs), minivans, and pickup trucks, have risen steadily for 20 years and now make up 46 percent of the U.S. market–-more than twice their market share as recently as 1983.

Growth in the light-duty truck market has been led recently by the explosive popularity of SUVs, which rose in sales from less than 200,000 in 1975 (less than 2 percent of the overall new light vehicle market) to almost 3 million in 1999 (20 percent of the market). Over the same period, market share for minivans and full-size vans doubled from 5 to 10 percent, and for pickup trucks grew from 13 to 16 percent. Between 1975 and 1999, market share for new passenger cars and wagons has fallen from 81 to 54 percent. Based on lower average fuel economies and projected longer useful lives, EPA estimates that the new light-duty trucks sold in 1999 will consume, over their lifetimes, almost 60 percent of the fuel used by all of the new light vehicles sold in 1999.

Market Share by Vehicle Type

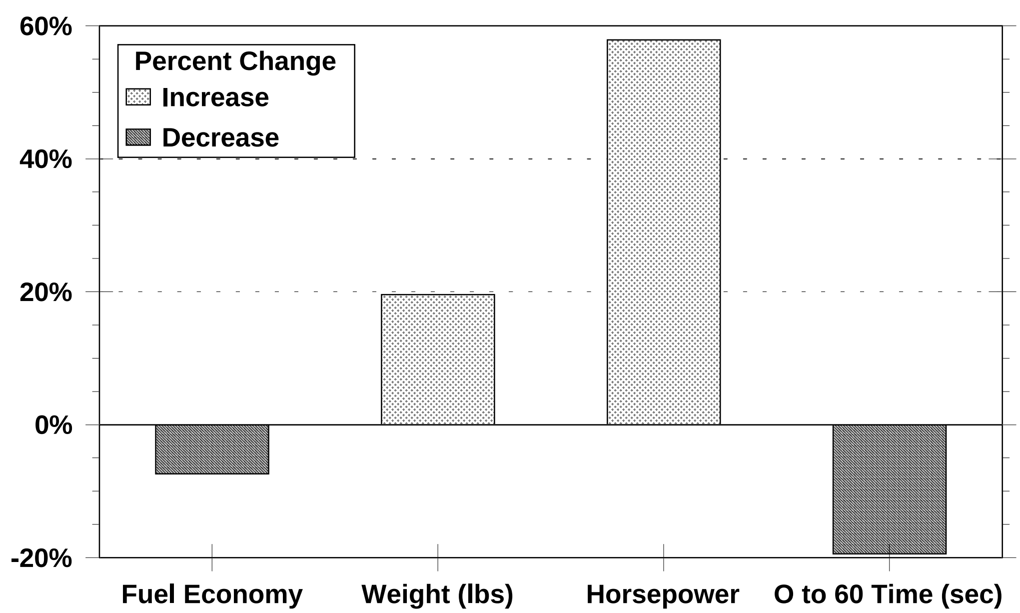


<u>Highlight #3</u>: <u>MPG is Being Traded for Weight and Performance</u>

More efficient technologies have continued to enter the new light vehicle fleet and are being used to increase light vehicle weight and performance rather than fuel economy. Based on accepted engineering relationships, had the new 1999 light vehicle fleet had the same average weight and performance as in 1986, it could have achieved 5 MPG higher fuel economy.

More efficient technologies-–such as engines with more valves and more sophisticated fuel injection systems, and transmissions with extra gears–-have continued to penetrate the new light vehicle fleet. The trend has clearly been to apply these new technologies to increase average new vehicle weight, power, and performance while maintaining fuel economy. This is reflected by heavier average vehicle weight (up 20 percent for new light vehicles since 1986), rising average horsepower (up 58 percent for new light vehicles since 1986), and lower 0 to 60 mile-per-hour acceleration time (19 percent faster for new light vehicles since 1986). During this same time, average new light vehicle fuel economy fell by 7 percent.

Percent Change Since 1986 in Light Vehicle Characteristics



I. Introduction

Light-duty automotive technology and fuel economy trends are examined herein, as in preceding papers in this series [1-26]*, using the latest and most complete EPA data available. The source database was frozen in March 1999.

Through model year 1997, the fuel economy and vehicle sales databases used for this report were formed from the most complete databases used for corporate average fuel economy standards (CAFE) and "gas guzzler" compliance purposes. For all practical purposes, these databases are stable and are not expected to change in the future. For model years 1998 and 1999, the fuel economy database used for this report was formed from the database used for the federal government's fuel economy public information programs: the *Fuel Economy Guide* and the MPG labels that are placed on new vehicles. The vehicle sales database for 1998 and 1999 used for this report was adjusted as necessary to take into account sales data available in trade publications at the time the database was frozen.

The MPG data in this series and this paper are unadjusted laboratory data, with no correction factors such as those used in both the *Fuel Economy Guide* and on vehicle labels for laboratory to on-road shortfall, for alternative fuels capability CAFÉ credits, or for "test procedure adjustment." Accordingly, the MPG values in this report are always slightly lower than those reported by the Department of Transportation and significantly higher than those in the *Fuel Economy Guide*. The laboratory fuel economy values are adjusted downward (the city value by 10 percent and the highway value by 22 percent) to obtain the real world projections used on new car labels and in the *Fuel Economy Guide*. These systematic differences do not influence the fuel economy and technology trends in this report.

Where only one MPG value is presented in this report, it is "55/45 combined MPG", i.e.,

$$MPG_{55/45} = 1 / (.55/ MPG_C + .45/MPG_H)$$

where MPG_C is the fuel economy on the EPA City Driving cycle and MPG_H is the fuel economy on the EPA Highway Driving cycle.

All vehicle weight data are based on inertia weight class (nominally curb weight plus 300 pounds). For vehicles with inertia weights up to 3000-pound inertia weight class, these

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* Numbers in brackets denote references listed at the end of the text.

classes have 250-pound increments; for vehicles 3500 pounds and above, 500-pound increments are used. All interior volume data for cars built after model year 1977 are based on the metric used to classify cars for the DOE/EPA *Fuel Economy Guide*. The car interior volume data in this paper combine that of the passenger compartment and trunk/cargo space. In the *Fuel Economy Guide*, interior volume is undefined for the two-seater class; for this series of reports, all two-seater cars have been assigned an interior volume value of 50 cubic feet.

The light truck data used in this series of papers include vehicles classified as light trucks with gross vehicle weight ratings (GVWR) up to 8,500 pounds for all years shown. Vehicles with GVWR between 8,500 and 10,000 pounds are not classified as light trucks by EPA and have not been included in the database. Omitting these vehicles influences the overall averages for all light-truck variables studied in this paper. Currently, total sales of trucks with GVWR between 8,500 and 10,000 pounds represent only about six or seven percent of the total sales of trucks with GVWR less than 8,500. To the extent that trucks with GVWR between 8,500 and 10,000 have lower fuel economy than the average for the trucks reported in this paper, the average fuel economy of the 0 to 10,000-pound fleet will be lower (and the fuel consumption higher) than the values reported here.

In addition to MPG, some tables in this paper contain alternate measures of vehicle fuel efficiency as used in reference 17. “Ton-MPG” is defined as a vehicle’s MPG multiplied by its inertia weight in tons. This metric provides an indication of a vehicle’s ability to move weight (i.e., its own plus payload). Ton-MPG is a measure of powertrain/drive line efficiency. Just as an increase in vehicle MPG at constant weight can be considered an improvement in a vehicle’s performance, an increase in a vehicle’s weight-carrying capacity at constant MPG can be considered an “improvement.”

“Cubic-feet-MPG” for cars is defined in this paper as the product of a car’s MPG and its interior volume, including trunk space. This metric associates a relative measure of a vehicle’s ability to transport both passengers and their cargo. An increase in vehicle volume at constant MPG could be considered an improvement just as an increase in MPG at constant volume can be.

“Cubic-feet-ton-MPG” is defined in this paper as a combination of the two previous metrics, i.e., a car’s MPG multiplied by its weight in tons and also by its interior volume. It ascribes vehicle utility to the ability to move both weight and volume.

This paper also includes an estimate of 0-60 MPH acceleration time, calculated from engine rated horsepower and vehicle inertia weight, from the relationship:

$$t = F\ (HP/WT)^{-f}$$

where the values used for F and f coefficients are .892 and .775 respectively for vehicles with automatic transmissions and .967 and .775 respectively for those with manual transmissions [27]. Other authors [28, 29, and 30] have evaluated the relationships between weight, horsepower, and 0 to 60 acceleration time and have calculated and published slightly different values for the F and f coefficients.

The 0 to 60 estimate used in this paper is intended to provide a quantitative "index" of vehicle performance capability. It is the authors' engineering judgment that, given the differences in test methods for measuring 0 to 60 time and given the fact that inertia weight is calculated from inertia weight classes, use of these other published values for the F and f coefficients would not result in a significantly different 0 to 60 relative performance estimate. The results of a similar calculation of estimated "top speed" are also included in some tables in this report.

For cars, vehicle classification as to vehicle type, size class, and manufacturer/origin generally follows fuel economy label, *Fuel Economy Guide*, and fuel economy standards protocols; exceptions are listed in Appendix A. In many of the passenger car tables, large sedans and wagons are aggregated as "Large," midsize sedans and wagons are aggregated as "Midsize," and "Small" includes all other cars. In some of the car tables, an alternative classification system is used, namely: Large Cars, Large Wagons, Midsize Cars, Midsize Wagons, Small Cars, and Small Wagons with the EPA "Two-Seater, Mini-Compact, Subcompact, and Compact" car classes combined into the "Small Car" class.

The truck classification scheme used for all model years in this paper is slightly different from that in previous papers in this series because pickups, vans, and sports utility vehicles (SUVs) are sometimes each subdivided as "Small," "Midsize," and "Large." These truck size classifications are based primarily on published wheelbase data according to the following criteria:

	Pickup	Van	SUV
Small	Less than 105"	Less than 109"	Less than 100"
Midsize	105" to 115"	109" to 124"	100" to 110"
Large	More than 115"	More than 124"	More than 110"

This classification scheme is similar to that used in many trade and consumer publications. For those vehicle nameplates with a variety of wheelbases, the size classification was determined by considering only the smallest wheelbase produced.

Grouping all vehicles into classes and then constructing time trends of parameters of interest like MPG can provide interesting and useful results. The results, however, are a strong function of the class definitions. Nowhere is this more important than in the definition of "Domestic" and "Import" truck or "Domestic," "European," and "Asian" car used in this series of papers.

Classification of a vehicle as a "Domestic" or "Import" truck, or "Domestic," "European Import," or "Asian Import" car is based on the authors' engineering judgment of where the majority of the vehicle's powertrain and emissions control system development and certification work was done. It is meant to be a tracking system for technical parameters related primarily to engine and transmission development and is not intended to be a replacement for other domestic/import definitions such as those used for fuel economy or tariff compliance programs.

Classes based on other definitions are possible, and results from these other classifications may also be useful.

Appendix B lists the model year 1997, 1998, and 1999 nameplates by size class and their sales-weighted average 55/45 MPG as of the data freeze date. Appendix C lists the model year 1999 role models used in the best in weight class analysis, their 55/45 MPG, and some of their technical characteristics such as transmission, cubic-inch displacement, and drive type. Appendix D contains information about the fleet grouped into market segment classes which reflect Domestic, European, and Asian design sources for cars and Domestic and Imported design sources for trucks.

Appendix E contains a series of tables in which the fleet is grouped into classes based on the number of engine cylinders. Appendix F, G, H, and I contain data in which the fleet is stratified by the number of engine valves per cylinder, by transmission class, by vehicle size class, and by inertia weight class respectively.

II. General Car and Truck Trends

Tables 1 and 2 give characteristics of passenger cars, light trucks, and all light-duty vehicles (cars and light trucks) for model years 1975 to 1999. Figure 1 shows that over the past decade, the fuel economy of the combined car and light-truck fleet has gradually declined and is now about 2.1 MPG, or about eight percent, below its peak of 25.9 MPG attained in 1987 and 1988. Both car and light-truck MPG has been relatively stable during this period; since 1986 cars have been within 0.6 MPG of 28 and light trucks with 0.7 MPG of 21.

For MY99, average MPG of all cars and trucks combined is projected to be 23.8 -- the lowest this value has been since 1981. The decline in the overall combined car/truck average is primarily due to the increasing market share of light trucks which have lower average fuel economy than cars. The increase in the light-truck share of the market is the most important trend in the light vehicle fleet over recent years and one which has not yet leveled off. The estimated light-truck share of the market has now reached 46 percent, more than double what it was in any year between 1975 and 1983.

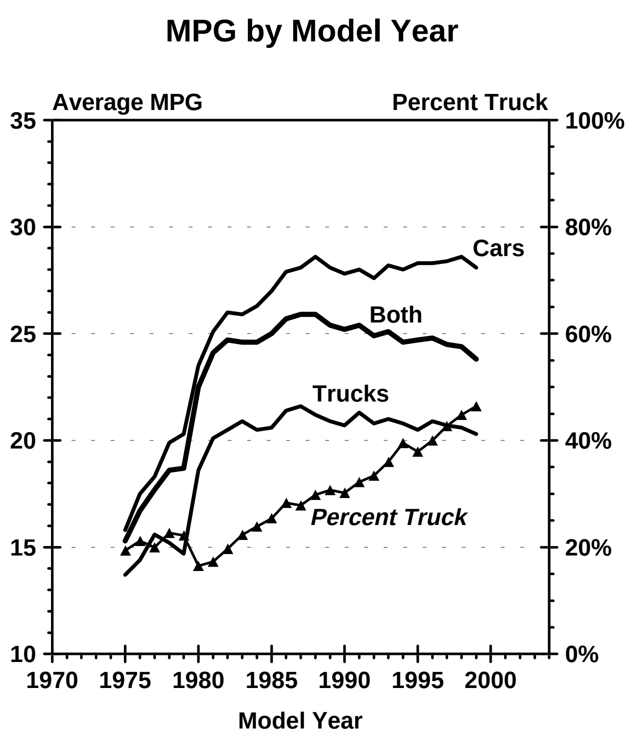

Figure 1

Table 1

FUEL ECONOMY CHARACTERISTICS OF
1975 TO 1999 LIGHT DUTY VEHICLES

MODEL YEAR	SALES (000)	FRAC	FUEL ECONOMY CITY	HWY	55/45	TON -MPG	CU-FT -MPG	CU-FT- TON-MPG
Cars								
1975	8237	0.806	13.7	19.5	15.8	32.3		
1976	9722	0.788	15.2	21.3	17.5	35.5		
1977	11300	0.800	16.0	22.3	18.3	36.4	2091	4021
1978	11175	0.773	17.2	24.5	19.9	35.9	2240	3926
1979	10794	0.778	17.7	24.6	20.3	35.4	2258	3878
1980	9443	0.835	20.3	29.0	23.5	36.6	2507	3841
1981	8733	0.827	21.7	31.1	25.1	38.9	2744	4161
1982	7819	0.803	22.3	32.7	26.0	40.1	2836	4273
1983	8002	0.777	22.1	32.7	25.9	40.7	2904	4426
1984	10675	0.761	22.4	33.3	26.3	41.1	2910	4425
1985	10791	0.746	23.0	34.3	27.0	42.0	2990	4548
1986	11015	0.717	23.7	35.5	27.9	42.6	3057	4585
1987	10731	0.722	23.9	35.9	28.1	42.8	3051	4569
1988	10736	0.702	24.2	36.6	28.6	43.7	3119	4693
1989	10018	0.693	23.8	36.3	28.1	43.8	3080	4723
1990	8810	0.698	23.4	36.0	27.8	44.2	3014	4746
1991	8524	0.678	23.6	36.3	28.0	44.3	3040	4746
1992	8108	0.666	23.1	36.3	27.6	44.9	3040	4877
1993	8457	0.640	23.6	37.0	28.2	45.4	3107	4930
1994	8402	0.605	23.4	36.9	28.0	45.7	3085	4956
1995	9396	0.620	23.6	37.6	28.3	46.4	3130	5045
1996	7893	0.600	23.5	37.6	28.3	46.5	3125	5078
1997	8347	0.573	23.7	37.7	28.4	46.7	3128	5079
1998	8078	0.552	23.8	38.2	28.6	47.6	3156	5178
1999	7876	0.536	23.4	37.3	28.1	47.7	3122	5238
Trucks								
1975	1987	0.194	12.1	16.2	13.7	28.4		
1976	2612	0.212	12.8	16.9	14.4	30.5		
1977	2823	0.200	14.0	18.1	15.6	33.0		
1978	3273	0.227	13.8	17.5	15.2	32.4		
1979	3088	0.222	13.4	16.8	14.7	32.1		
1980	1863	0.165	16.5	21.9	18.6	36.3		
1981	1821	0.173	17.8	23.9	20.1	38.8		
1982	1914	0.197	18.1	24.4	20.5	39.7		
1983	2300	0.223	18.3	25.2	20.9	39.9		
1984	3345	0.239	17.9	24.8	20.5	39.3		
1985	3669	0.254	18.0	24.9	20.6	39.6		
1986	4350	0.283	18.8	25.9	21.4	40.4		
1987	4134	0.278	18.8	26.5	21.6	40.5		
1988	4559	0.298	18.3	26.2	21.2	40.9		
1989	4435	0.307	18.1	25.8	20.9	41.2		
1990	3805	0.302	17.8	25.9	20.7	41.8		
1991	4049	0.322	18.3	26.6	21.3	42.2		
1992	4064	0.334	17.8	26.2	20.8	42.4		
1993	4754	0.360	17.9	26.5	21.0	42.9		
1994	5481	0.395	17.8	26.1	20.8	43.2		
1995	5749	0.380	17.5	25.9	20.5	43.2		
1996	5254	0.400	17.7	26.5	20.8	44.3		
1997	6224	0.427	17.6	26.2	20.7	45.0		
1998	6555	0.448	17.5	26.2	20.6	44.6		
1999	6822	0.464	17.3	25.7	20.3	45.1		

Table 1 (Continued)

FUEL ECONOMY CHARACTERISTICS OF
1975 TO 1999 LIGHT DUTY VEHICLES

MODEL YEAR	SALES (000)	FRAC	FUEL ECONOMY CITY	HWY	55/45	TON -MPG
Both						
1975	10224	1.000	13.4	18.7	15.3	31.6
1976	12334	1.000	14.6	20.2	16.7	34.4
1977	14123	1.000	15.6	21.3	17.7	35.7
1978	14448	1.000	16.3	22.5	18.6	35.1
1979	13882	1.000	16.5	22.3	18.7	34.7
1980	11306	1.000	19.6	27.5	22.5	36.6
1981	10554	1.000	20.9	29.5	24.1	38.9
1982	9732	1.000	21.3	30.7	24.7	40.0
1983	10302	1.000	21.2	30.6	24.6	40.5
1984	14020	1.000	21.2	30.8	24.6	40.7
1985	14460	1.000	21.5	31.3	25.0	41.4
1986	15365	1.000	22.1	32.2	25.7	42.0
1987	14865	1.000	22.2	32.6	25.9	42.1
1988	15295	1.000	22.1	32.7	25.9	42.9
1989	14453	1.000	21.7	32.3	25.4	43.0
1990	12615	1.000	21.4	32.2	25.2	43.5
1991	12573	1.000	21.6	32.5	25.4	43.6
1992	12172	1.000	21.0	32.1	24.9	44.1
1993	13211	1.000	21.2	32.4	25.1	44.5
1994	13883	1.000	20.8	31.7	24.6	44.7
1995	15145	1.000	20.8	32.1	24.7	45.2
1996	13147	1.000	20.8	32.2	24.8	45.7
1997	14571	1.000	20.6	31.8	24.5	45.9
1998	14633	1.000	20.5	31.7	24.4	46.3
1999	14699	1.000	20.1	30.9	23.8	46.5

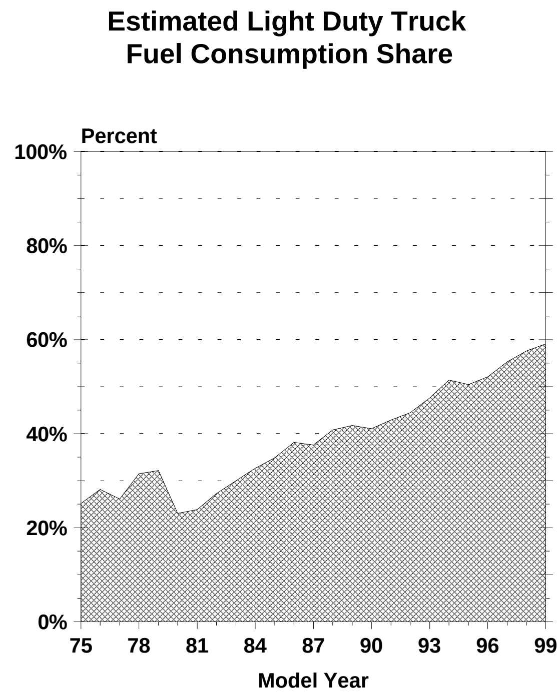

Figure 2

The trends in truck market share, car and truck MPG, and an estimate of vehicle travel can be combined to estimate the fraction of all light-vehicle fuel consumption that can be attributed to light trucks. The values plotted in Figure 2 represent the fuel-consumption fraction, by model year, associated with light trucks.

Considering the fuel used by both passenger cars and light trucks as 100 percent, Figure 2 shows that, on a model year basis, the estimated share of the fuel consumed by light trucks has exceeded 50 percent for the past five model years and is almost 60 percent. Note that this calculation uses the same useful life values that EPA considers for the purposes of emissions regulations, namely 100,000 miles for cars and 120,000 miles for trucks. The calculation also assumes that the relative city and highway driving fractions are the same for both cars and trucks.

Table 2 gives vehicle size and design characteristics of light-duty vehicles. Average interior volume of cars has changed very little since 1977. Between 1975 and 1984 (see Figure 3), average inertia weight for cars decreased nearly a thousand pounds; vehicle performance, as measured by estimated 0 to 60 time, was relatively constant; and average MPG increased from 15.8 to 26.3.

For the next five years, passenger car inertia weight remained relatively constant; 0 to 60 time decreased by about a second; and fuel economy reached a peak of 28.6 in 1988, then dropped to 28.1 the next year. With three minor exceptions, passenger car inertia weight has increased every year since 1989 and is now about 300 pounds higher than it was then. Similarly, estimated 0 to 60 time has decreased each year and is now two seconds less than it was a decade ago.

Table 2

VEHICLE SIZE AND DESIGN CHARACTERISTICS OF 1975 TO 1999 LIGHT DUTY VEHICLES

	<--------- MEASURED CHARACTERISTICS ---------->								<---------------- PERCENT BY --------------->						
MODEL YEAR	SALES (000)	FRAC	55/45 MPG	VOL CU-FT	WGHT LB	0-60 TIME	TOP SPD	HP/ WT	VEHICLE SIZE SMALL	MID	LARGE	DESIGN DOM	EUR	ASIA	IMPORT
Cars															
1975	8237	.806	15.8		4057	14.2	111	.0331	55.4	23.3	21.3	81.6	8.2	10.3	18.4
1976	9722	.788	17.5		4058	14.4	110	.0324	55.4	25.2	19.4	84.9	5.4	9.7	15.1
1977	11300	.800	18.3	110	3943	14.0	111	.0334	51.9	24.5	23.5	82.2	5.5	12.2	17.8
1978	11175	.773	19.9	109	3587	13.7	111	.0342	44.7	34.4	21.0	80.2	6.3	13.5	19.8
1979	10794	.778	20.3	108	3484	13.8	110	.0338	43.7	34.2	22.1	80.4	5.6	14.0	19.6
1980	9443	.835	23.5	104	3101	14.3	107	.0321	54.4	34.4	11.3	71.2	8.4	20.4	28.8
1981	8733	.827	25.1	106	3075	14.4	106	.0319	51.5	36.4	12.2	71.7	6.0	22.3	28.3
1982	7819	.803	26.0	106	3054	14.4	106	.0320	56.5	31.0	12.5	70.4	6.3	23.3	29.6
1983	8002	.777	25.9	108	3111	14.0	108	.0330	53.1	31.8	15.1	71.0	5.5	23.5	29.0
1984	10675	.761	26.3	107	3098	13.8	109	.0338	57.4	29.4	13.2	75.9	6.0	18.1	24.1
1985	10791	.746	27.0	108	3092	13.3	111	.0354	55.7	28.9	15.4	72.3	6.2	21.6	27.7
1986	11015	.717	27.9	107	3040	13.2	111	.0359	59.5	27.9	12.6	68.2	6.6	25.1	31.8
1987	10731	.722	28.1	106	3030	13.0	112	.0365	63.5	24.3	12.2	61.6	6.9	31.5	38.4
1988	10736	.702	28.6	107	3046	12.8	113	.0374	64.8	22.3	12.8	61.2	6.3	32.5	38.8
1989	10018	.693	28.1	107	3099	12.5	115	.0386	58.3	28.2	13.5	61.9	5.5	32.6	38.1
1990	8810	.698	27.8	107	3175	12.1	117	.0401	58.6	28.7	12.8	56.8	5.0	38.2	43.2
1991	8524	.678	28.0	106	3153	11.8	118	.0413	61.5	26.2	12.3	56.2	4.6	39.2	43.8
1992	8108	.666	27.6	108	3239	11.5	120	.0427	56.5	27.8	15.6	58.3	4.1	37.7	41.7
1993	8457	.640	28.2	108	3207	11.6	120	.0425	57.2	29.5	13.3	60.4	3.4	36.2	39.6
1994	8402	.605	28.0	108	3251	11.4	121	.0432	58.5	26.1	15.4	55.8	4.0	40.2	44.2
1995	9396	.620	28.3	108	3262	10.9	125	.0460	57.3	28.6	14.0	58.5	5.4	36.1	41.5
1996	7893	.600	28.3	108	3281	10.8	125	.0463	54.3	32.0	13.6	57.8	5.1	37.0	42.2
1997	8347	.573	28.4	108	3274	10.7	126	.0469	55.0	30.7	14.3	55.0	6.5	38.5	45.0
1998	8078	.552	28.6	108	3306	10.6	127	.0477	48.3	40.8	11.0	56.1	7.7	36.2	43.9
1999	7876	.536	28.1	109	3382	10.5	128	.0483	45.3	39.7	15.0	54.4	9.2	36.4	45.6

Table 2 (continued)

VEHICLE SIZE AND DESIGN CHARACTERISTICS OF 1975 TO 1999 LIGHT DUTY VEHICLES

	<----- MEASURED CHARACTERISTICS					------->		<---------- PERCENT BY			--------->	
MODEL YEAR	SALES (000)	FRAC	55/45 MPG	WGHT LB	0-60 TIME	TOP SPD	HP/ WT	VEHICLE SIZE SMALL	MID	LARGE	DESIGN DOM	IMPORT
Trucks												
1975	1987	.194	13.7	4072	13.6	114	.0347	10.9	24.2	64.9	88.7	11.3
1976	2612	.212	14.4	4154	13.8	113	.0338	9.0	20.3	70.7	90.9	9.1
1977	2823	.200	15.6	4135	13.3	115	.0354	11.1	20.3	68.5	88.5	11.5
1978	3273	.227	15.2	4151	13.4	114	.0349	10.9	22.7	66.3	89.1	10.9
1979	3088	.222	14.7	4251	14.3	111	.0324	15.2	19.5	65.3	84.7	15.3
1980	1863	.165	18.6	3868	14.5	108	.0311	28.4	17.6	54.0	69.4	30.6
1981	1821	.173	20.1	3805	14.6	108	.0309	23.2	19.1	57.7	72.0	28.0
1982	1914	.197	20.5	3805	14.5	109	.0315	21.1	31.0	47.9	76.3	23.7
1983	2300	.223	20.9	3763	14.5	108	.0311	16.6	45.9	37.6	78.5	21.5
1984	3345	.239	20.5	3782	14.7	108	.0309	19.5	46.4	34.1	78.0	22.0
1985	3669	.254	20.6	3795	14.1	110	.0325	19.2	48.5	32.3	80.1	19.9
1986	4350	.283	21.4	3737	14.0	110	.0329	23.5	48.5	28.0	70.3	29.7
1987	4134	.278	21.6	3712	13.3	113	.0350	19.9	59.6	20.6	72.3	27.7
1988	4559	.298	21.2	3841	12.9	115	.0365	15.0	57.2	27.8	81.1	18.9
1989	4435	.307	20.9	3921	12.8	116	.0371	13.9	58.9	27.2	81.9	18.1
1990	3805	.302	20.7	4005	12.6	117	.0376	13.4	59.0	27.6	80.3	19.7
1991	4049	.322	21.3	3948	12.6	117	.0379	11.4	67.2	21.4	79.7	20.3
1992	4064	.334	20.8	4055	12.5	118	.0381	10.4	64.0	25.6	82.2	17.8
1993	4754	.360	21.0	4073	12.1	120	.0398	8.8	65.3	25.9	82.6	17.4
1994	5481	.395	20.8	4133	12.0	121	.0401	9.7	62.3	28.0	82.9	17.1
1995	5749	.380	20.5	4184	12.0	121	.0401	8.6	63.5	27.9	80.8	19.2
1996	5254	.400	20.8	4224	11.5	124	.0422	6.5	67.1	26.4	84.7	15.3
1997	6224	.427	20.7	4331	11.4	125	.0428	10.0	53.4	36.7	83.3	16.7
1998	6555	.448	20.6	4319	11.2	127	.0438	7.5	58.3	34.2	82.6	17.4
1999	6822	.464	20.3	4433	11.1	127	.0440	7.8	55.5	36.7	81.3	18.7
Both												
1975	10224	1.000	15.3	4060	14.1	112	.0334	46.8	23.5	29.8	82.9	17.1
1976	12334	1.000	16.7	4079	14.3	111	.0327	45.6	24.2	30.3	86.2	13.8
1977	14123	1.000	17.7	3981	13.8	112	.0338	43.8	23.7	32.5	83.5	16.5
1978	14448	1.000	18.6	3715	13.6	112	.0343	37.0	31.7	31.2	82.2	17.8
1979	13882	1.000	18.7	3655	13.9	110	.0335	37.3	30.9	31.7	81.4	18.6
1980	11306	1.000	22.5	3227	14.3	107	.0319	50.1	31.6	18.3	70.9	29.1
1981	10554	1.000	24.1	3201	14.4	107	.0318	46.6	33.4	20.0	71.7	28.3
1982	9732	1.000	24.7	3201	14.4	107	.0319	49.6	31.0	19.5	71.6	28.4
1983	10302	1.000	24.6	3257	14.1	108	.0325	44.9	34.9	20.1	72.7	27.3
1984	14020	1.000	24.6	3261	14.0	109	.0331	48.4	33.4	18.2	76.4	23.6
1985	14460	1.000	25.0	3271	13.5	110	.0347	46.5	33.9	19.7	74.2	25.8
1986	15365	1.000	25.7	3237	13.4	111	.0351	49.3	33.7	17.0	68.8	31.2
1987	14865	1.000	25.9	3220	13.1	112	.0361	51.4	34.1	14.5	64.6	35.4
1988	15295	1.000	25.9	3283	12.8	114	.0372	50.0	32.7	17.3	67.1	32.9
1989	14453	1.000	25.4	3351	12.5	115	.0382	44.7	37.6	17.7	68.1	31.9
1990	12615	1.000	25.2	3426	12.2	117	.0393	44.9	37.8	17.2	63.9	36.1
1991	12573	1.000	25.4	3409	12.1	118	.0402	45.3	39.4	15.2	63.8	36.2
1992	12172	1.000	24.9	3512	11.8	120	.0412	41.1	39.9	19.0	66.3	33.7
1993	13211	1.000	25.1	3518	11.8	120	.0415	39.8	42.4	17.8	68.4	31.6
1994	13883	1.000	24.6	3599	11.7	121	.0420	39.2	40.4	20.4	66.5	33.5
1995	15145	1.000	24.7	3612	11.3	123	.0437	38.8	41.9	19.3	67.0	33.0
1996	13147	1.000	24.8	3658	11.1	125	.0447	35.2	46.0	18.7	68.6	31.4
1997	14571	1.000	24.5	3726	11.0	126	.0451	35.8	40.4	23.9	67.1	32.9
1998	14633	1.000	24.4	3760	10.8	127	.0459	30.0	48.6	21.4	68.0	32.0
1999	14699	1.000	23.8	3870	10.8	128	.0463	27.9	47.0	25.0	66.9	33.1

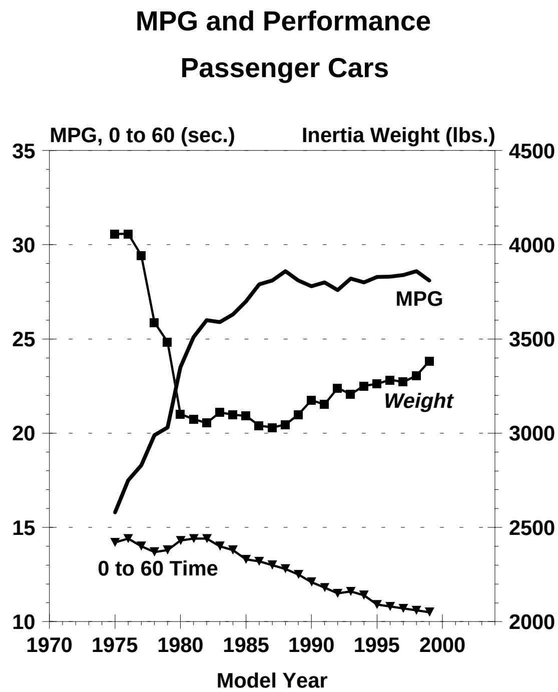

Figure 3

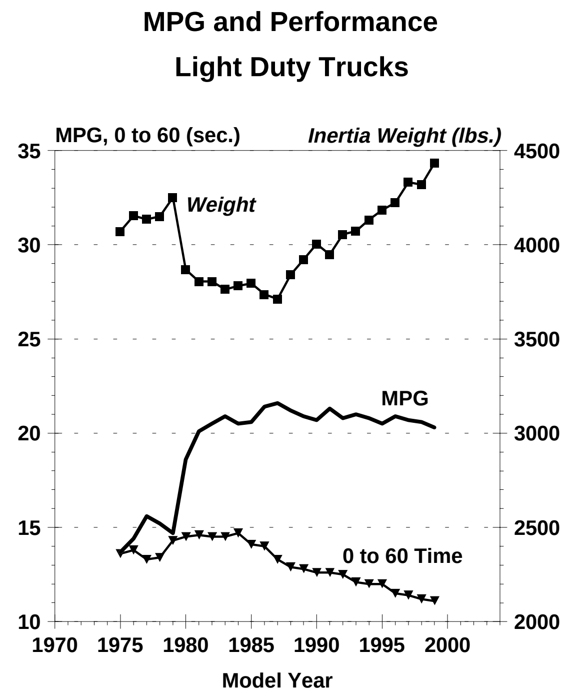

Figure 4

As indicated in Figure 4, average inertia weight for trucks reached a minimum value of 3737 pounds in 1985 and has increased nearly 700 pounds since then. Between 1975 and 1984, estimated 0 to 60 time for trucks increased from 13.6 to 14.7 seconds and has since decreased to 11.1 seconds. For model year 1999, light truck fuel economy is nearly 50 percent higher than it was in 1975, but most of this increase occurred between 1975 and 1981.

Figure 5 compares another estimated performance metric: top speed, which like estimated 0 to 60 time is calculated from the ratio of horsepower to weight. The trends for both cars and trucks are very similar and are difficult to distinguish. As with 0 to 60 time, estimated top speed for both cars and trucks remained relatively constant for a few years in the late 70's, then dropped slightly during the early 80's, and has since increased from a nominal 110 MPH in 1984 to over 125 MPH in 1999.

Figures 3 and 4 indicate that the weight increase that has occurred in recent years has not been accompanied by a substantial reduction in MPG. Cars and light trucks thus are getting more efficient at moving their weight around. Accounting for vehicle weight in a measure of vehicle efficiency can be accomplished by looking at ton-MPG which, as previously mentioned, is defined for the purpose of this paper as a

Estimated Top Speed by Model Year

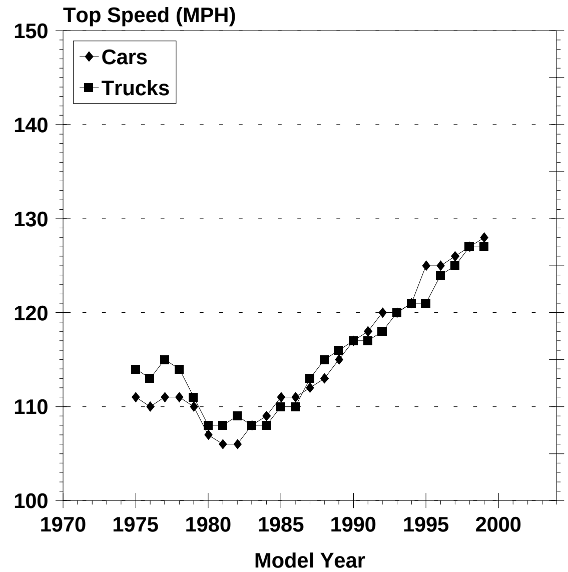

Figure 5

Ton-MPG by Model Year

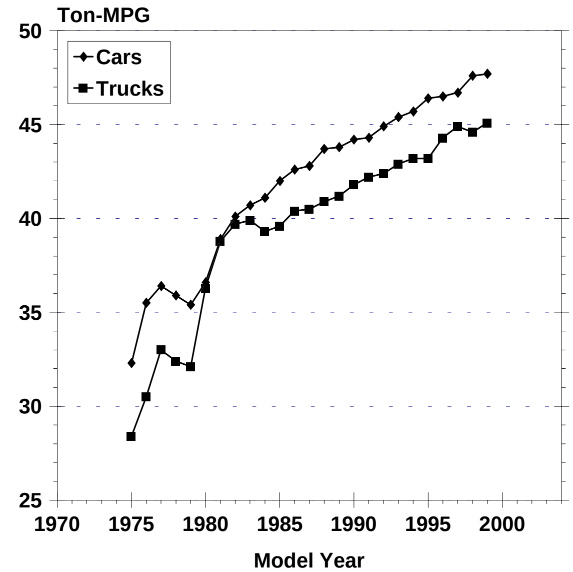

Figure 6

vehicle's weight in tons times its MPG. Figure 6 shows that since 1975 cars have improved in ton-MPG by about 48 percent; trucks by about 58 percent. On a ton-MPG basis, however, trucks lag behind the performance of cars by about a half dozen years, while on an MPG basis (see Figure 1), they are much farther behind.

Figures 7 and 8 show the cumulative distribution of MPG for model year 1999 passenger cars and trucks, respectively. About 80 percent of the 1999 cars get between 25 and 35 MPG; less than 2 percent get less than 22 MPG; and about 2 percent get more than 38 MPG. Similarly for trucks, about 80 percent get between 16 and 25 MPG; less than 5 percent get less than 16 MPG; and less than 3 percent get more than 28 MPG.

Figure 9 shows average weight and interior volume for model year 1999 cars by MPG band. EPA does not define interior volume for trucks, but similar weight data by MPG band for trucks is shown in Figure 10 and estimated 0 to 60 data by MPG band for 1999 and 1986 cars and trucks are shown in Figures 11 and 12, respectively. The results show that vehicles with high MPG have less performance, are lighter, and (for passenger cars) tend to have smaller interior volumes than vehicles with low MPG.

Cumulative Sales Fraction
1999 Passenger Cars

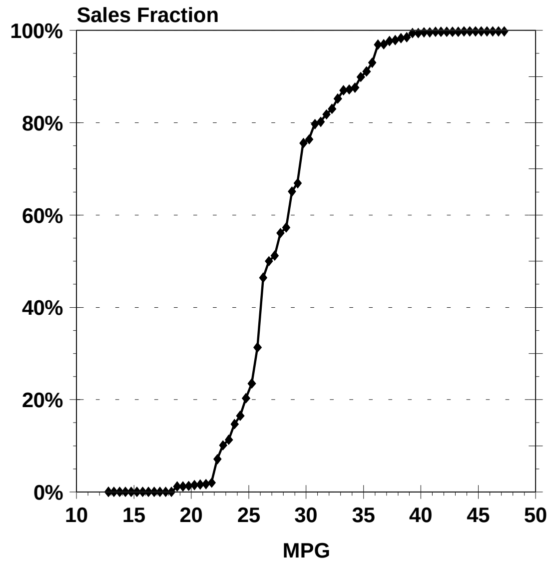

Figure 7

Cumulative Sales Fraction
1999 Light Duty Trucks

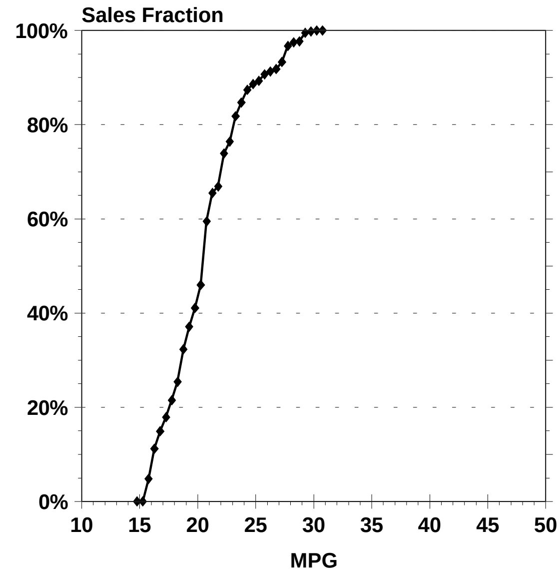

Figure 8

Inertia Weight and Interior Volume vs MPG
1999 Passenger Cars

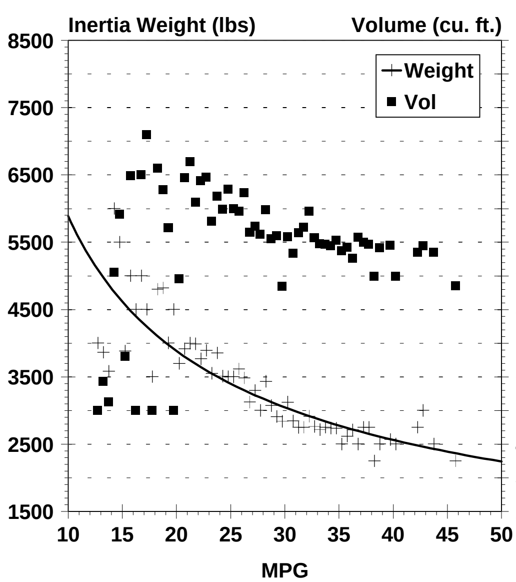

Figure 9

Inertia Weight vs MPG
1999 Light Duty Trucks

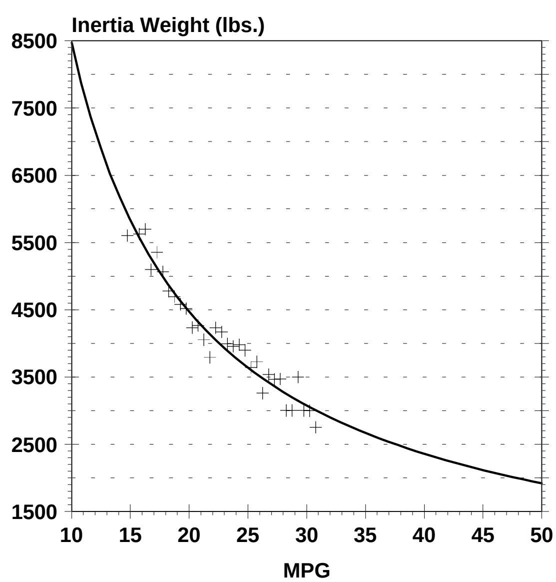

Figure 10

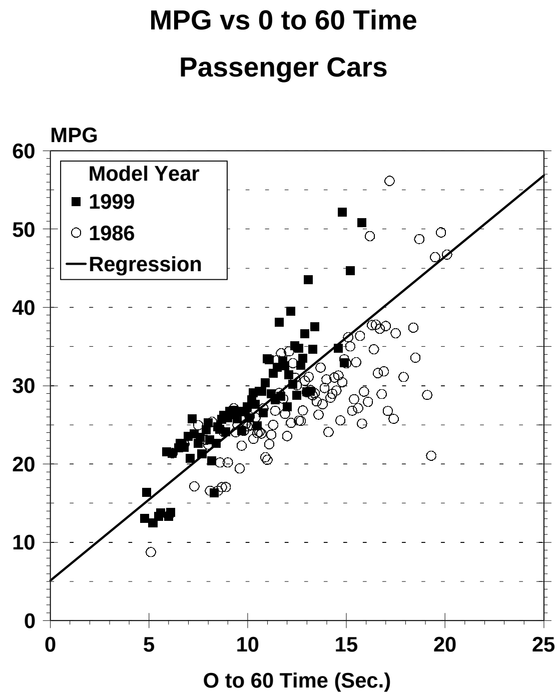

Figure 11

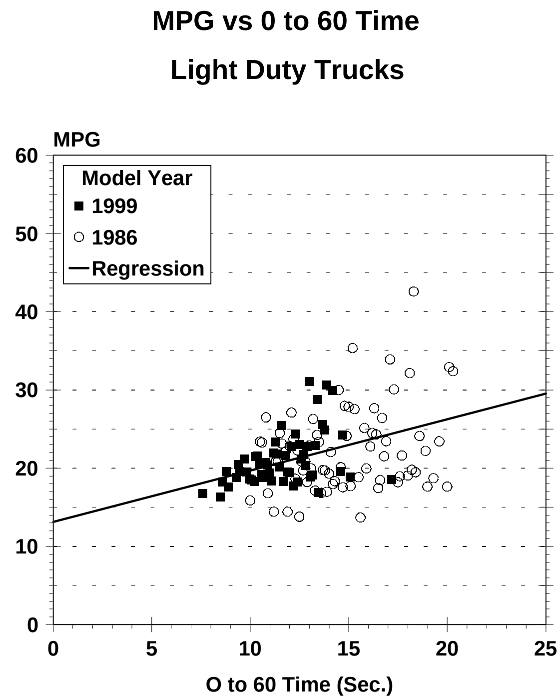

Figure 12

The MPG/performance interdependence was quantified by means of the regression lines shown in Figures 11 and 12. These regression lines indicate the sensitivity of MPG to estimated 0 to 60 time. Using these sensitivities, MPG data at one level can be adjusted to what it would have been at another 0 to 60 level.

Table 3 and Figures 13 and 14 provide estimates of what the MPG of the car and truck fleet would have been each model year if:

(1) the average acceleration time was kept at 13.2 seconds, the average value cars achieved in 1986 and about the value that trucks achieved the following year;

(2) the weight mix had been kept the same as in 1986; and

(3) both the 1986 weight distribution and average acceleration time were 13.2 seconds.

Had there not been a trade-off in weight and performance as measured by the 0 to 60 indicator, MY99 cars might have averaged 33 MPG, and MY99 trucks might have averaged 25 MPG. In both cases, these values are about five MPG higher than the actual MY99 values. Note that for passenger cars, all three scenarios give the same MPG results as the actual MPG values for MY86.

Table 3

Effect of Weight and 0 to 60 Time Changes
On 1975 to 1999 Light Duty Vehicles

Model Year	Actual 0 to 60 Time	Actual Inertia Weight	Actual 55/45 MPG	<-- Adjusted 55/45 MPG Using --> 13.2 Sec. 0 to 60	1986 Wt. Mix	Both 0 to 60 & 1986 Wt. Mix
Cars						
1975	14.2	4058	15.8	15.2	20.6	19.4
1976	14.4	4059	17.5	16.6	22.5	20.9
1977	14.0	3944	18.3	17.8	23.2	22.1
1978	13.7	3588	19.9	19.5	22.9	22.2
1979	13.8	3485	20.3	19.8	22.6	21.9
1980	14.3	3101	23.5	22.5	23.7	22.7
1981	14.4	3076	25.1	24.0	25.0	24.1
1982	14.4	3054	26.0	24.9	25.9	24.9
1983	14.0	3112	25.9	25.2	26.4	25.6
1984	13.8	3099	26.3	25.8	26.6	26.2
1985	13.3	3093	27.0	26.9	27.3	27.2
1986	13.2	3041	27.9	27.9	27.9	27.9
1987	13.0	3031	28.1	28.2	28.0	28.2
1988	12.8	3047	28.6	29.0	28.7	29.1
1989	12.5	3099	28.1	28.9	28.7	29.4
1990	12.1	3176	27.8	28.9	29.0	29.9
1991	11.8	3154	28.0	29.4	29.0	30.3
1992	11.5	3240	27.6	29.3	29.3	30.8
1993	11.6	3207	28.2	29.8	29.6	31.1
1994	11.4	3251	28.0	29.8	29.8	31.3
1995	10.9	3263	28.3	30.7	30.3	32.5
1996	10.8	3282	28.3	30.7	30.4	32.6
1997	10.7	3274	28.4	31.0	30.4	32.6
1998	10.6	3307	28.6	31.4	30.8	33.2
1999	10.5	3383	28.1	30.9	30.7	33.1
Trucks						
1975	13.6	4072	13.7	13.4	15.1	14.6
1976	13.8	4155	14.4	14.0	16.0	15.4
1977	13.3	4135	15.6	15.5	17.5	17.2
1978	13.4	4151	15.2	15.1	17.4	17.1
1979	14.3	4252	14.7	14.0	16.7	15.9
1980	14.5	3869	18.6	17.6	18.6	17.4
1981	14.6	3806	20.1	19.0	20.3	19.1
1982	14.5	3806	20.5	19.4	20.7	19.5
1983	14.5	3763	20.9	19.7	21.0	19.9
1984	14.7	3782	20.5	19.3	20.7	19.5
1985	14.1	3795	20.6	19.9	20.9	20.2
1986	14.0	3738	21.4	20.8	21.4	20.8
1987	13.3	3713	21.6	21.4	21.5	21.3
1988	12.9	3841	21.2	21.3	21.7	21.9
1989	12.8	3921	20.9	21.1	21.7	22.0
1990	12.6	4005	20.7	21.1	22.0	22.4
1991	12.6	3948	21.3	21.7	22.2	22.5
1992	12.5	4056	20.8	21.2	22.2	22.7
1993	12.1	4073	21.0	21.7	22.5	23.2
1994	12.0	4134	20.8	21.6	22.6	23.4
1995	12.0	4184	20.5	21.3	22.5	23.4
1996	11.5	4255	20.8	22.0	23.0	24.3
1997	11.2	4332	20.7	22.0	23.2	24.5
1998	11.2	4320	20.6	22.1	23.3	24.8
1999	11.1	4433	20.3	21.8	23.6	25.2

Effect of Weight and 0 to 60 Changes on Passenger Car MPG

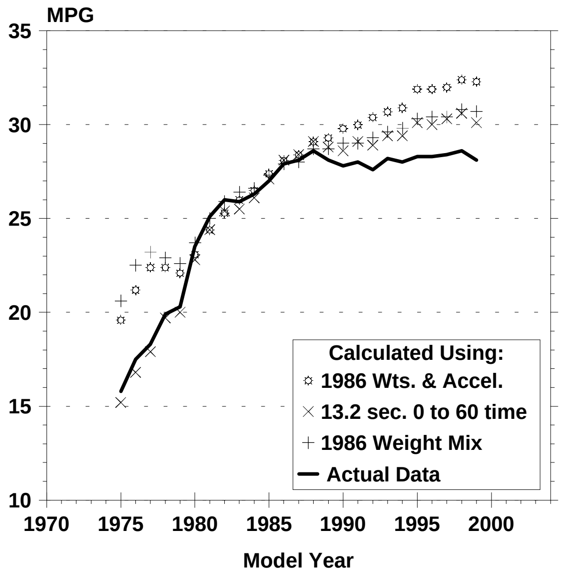

Figure 13

Effect of Weight and 0 to 60 Changes on Light Duty Truck MPG

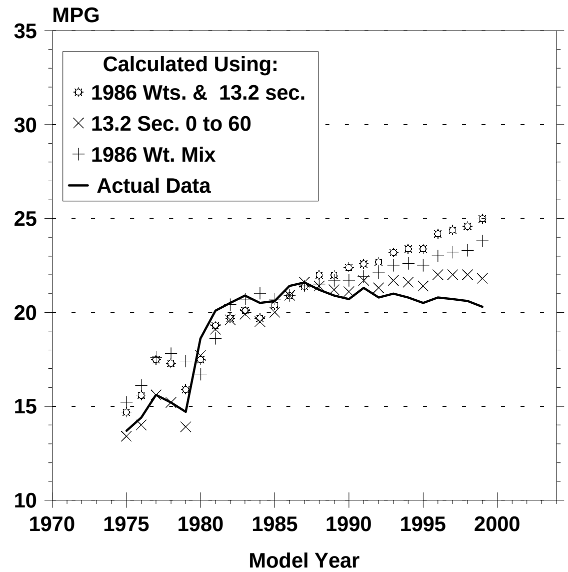

Figure 14

III. Technology Trends

Vehicle technologies studied in this report include engines, transmissions, and usage of front-, rear-, and four-wheel drive. Overall trends in these technologies are presented in Table 4. Additional data stratified by transmission type and number of gears, by number of engine cylinders, and by number of valves per cylinder are presented in Appendices E, F, and G, respectively.

Figures 15 and 16 compare the trends since 1975 for horsepower (HP), displacement (CID), and specific power or horsepower per cubic inch (HP/CID) for passenger cars and light trucks. In both cases, significant CID reductions occurred in the late 1970's and early 1980's. Since 1985, however, engine displacement has continued to decrease for cars, but not for light trucks. For both vehicle types, average horsepower has increased over 60 percent since 1981. Engines in both vehicle types, thus, have also improved in HP/CID, with engines used in passenger cars improving at a faster rate than truck engines. In fact, passenger car engines are projected to achieve 1.0 HP/CID this year, compared to .8 HP/CID for trucks. Current engine-related data are summarized in Table 5.

Passenger Car Horsepower, CID and Horsepower per CID

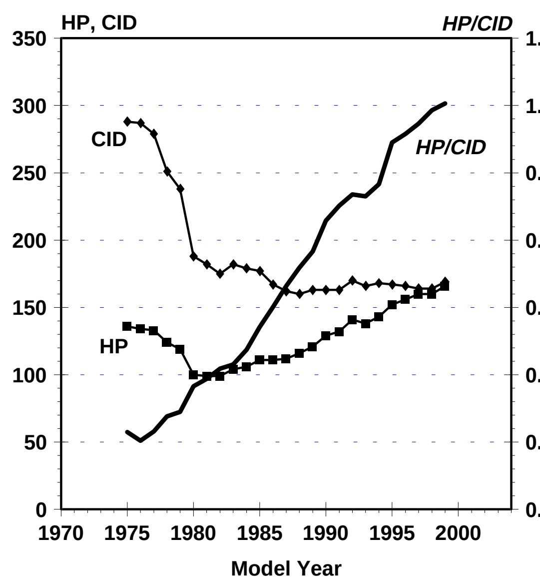

Figure 15

Light Duty Truck Horsepower, CID and Horsepower per CID

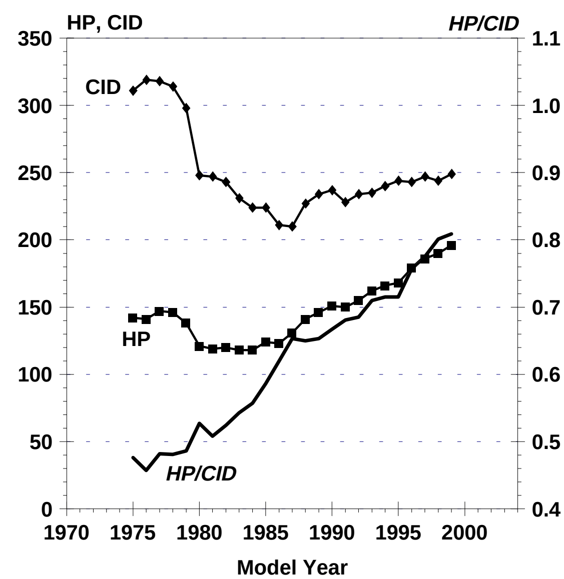

Figure 16

TABLE 4

VEHICLE SIZE AND DESIGN CHARACTERISTICS OF 1975 TO 1999 LIGHT DUTY VEHICLES

<---- MEASURED CHARACTERISTICS—><--------------- PERCENT OF VEHICLES EQUIPPED WITH ---------------->

MODEL YEAR	SALES (000)	FRAC	55/45 MPG	ENGINE CID	HP	HP/ CID	DRIVETRAIN FRONT	4WD	TRANSMISSION MANUAL	LOCK	FUEL METERING FI	TBI	PORT	CARB	DSL	FOUR VALVE
Cars																
1975	8237	.806	15.8	288	136	515	6.5		19.9		5.1		5.1	94.6	.2	
1976	9722	.788	17.5	287	134	.502	5.8		17.1		3.2		3.2	96.6	.3	
1977	11300	.800	18.3	279	133	.516	6.8		16.8		4.2		4.2	95.3	.5	
1978	11175	.773	19.9	251	124	.538	9.6		20.2	6.7	5.1		5.1	94.0	.9	
1979	10794	.778	20.3	238	119	.545	11.9	.3	22.3	8.0	4.7		4.7	93.2	2.1	
1980	9443	.835	23.5	188	100	.583	29.7	.9	31.9	16.5	6.9	.7	6.2	88.7	4.4	
1981	8733	.827	25.1	182	99	.594	37.0	.7	30.4	33.3	8.8	2.6	6.1	85.3	5.9	
1982	7819	.803	26.0	175	99	.609	45.6	.8	29.7	51.4	17.0	9.8	7.2	78.4	4.7	
1983	8002	.777	25.9	182	104	.615	47.3	3.1	27.4	56.7	28.3	18.9	9.5	69.6	2.1	
1984	10675	.761	26.3	179	106	.637	53.7	1.0	24.2	58.3	39.4	24.4	15.0	58.9	1.7	
1985	10791	.746	27.0	177	111	.671	61.6	2.1	23.6	58.7	53.5	32.0	21.4	45.6	.9	
1986	11015	.717	27.9	167	111	.701	71.1	1.1	24.8	58.0	65.1	28.4	36.7	34.5	.3	1.6
1987	10731	.722	28.1	162	112	.732	77.0	1.1	24.9	59.5	73.0	30.5	42.5	26.8	.3	5.6
1988	10736	.702	28.6	160	116	.759	81.7	.8	24.3	66.1	83.7	30.0	53.7	16.3		10.4
1989	10018	.693	28.1	163	121	.783	82.5	1.0	21.0	69.3	90.2	27.8	62.4	9.7		12.8
1990	8810	.698	27.8	163	129	.829	84.6	1.0	19.6	72.9	98.6	21.1	77.5	1.4		25.7
1991	8524	.678	28.0	163	132	.851	83.2	1.4	20.5	73.5	99.8	21.8	78.0		.1	28.2
1992	8108	.666	27.6	170	141	.868	80.8	1.1	17.3	76.4	99.9	10.4	89.5		.1	29.7
1993	8457	.640	28.2	166	138	.865	85.1	1.2	17.8	76.9	100.0	8.4	91.6			32.8
1994	8402	.605	28.0	168	143	.883	84.2	.7	16.0	79.4	100.0	5.0	95.0			39.0
1995	9396	.620	28.3	167	152	.945	82.0	1.2	16.2	81.9	99.9	1.2	98.8		.1	52.1
1996	7893	.600	28.3	165	154	.958	86.5	1.5	14.9	83.5	99.9	1.1	98.8		.1	56.2
1997	8347	.573	28.4	164	156	.975	86.5	1.7	13.5	85.9	99.9	.8	99.1		.1	57.5
1998	8078	.552	28.6	164	160	.993	87.3	2.1	13.8	83.7	99.7	.2	99.5		.3	58.8
1999	7876	.536	28.1	169	166	1.003	84.7	2.5	13.7	85.9	99.7		99.6		.3	60.3
Trucks																
1975	1987	.194	13.7	311	142	.476		17.1	37.0		.1			99.9		
1976	2612	.212	14.4	319	141	.457		22.9	34.8		.1			99.9		
1977	2823	.200	15.6	318	147	.482		23.6	32.0		.1			99.9		
1978	3273	.227	15.2	314	146	.481		29.0	32.4		.1			99.1	.8	
1979	3088	.222	14.7	298	138	.486		18.0	35.2	2.1	.3			97.9	1.8	
1980	1863	.165	18.6	248	121	.527	1.4	25.0	53.0	24.6	1.7			94.9	3.5	
1981	1821	.173	20.1	247	119	.508	1.9	20.1	51.6	31.1	1.1			93.3	5.6	
1982	1914	.197	20.5	243	120	.524	1.7	20.0	45.7	33.2	.7			90.0	9.3	
1983	2300	.223	20.9	231	118	.543	1.4	25.8	45.9	36.1	.6			94.7	4.7	
1984	3345	.239	20.5	224	118	.557	4.9	31.0	42.1	35.1	2.6			95.1	2.3	
1985	3669	.254	20.6	224	124	.586	7.1	30.6	37.1	42.2	12.3	.2		86.7	1.1	
1986	4350	.283	21.4	211	123	.620	5.9	30.3	42.7	42.0	40.5	18.7	21.8	58.7	.7	
1987	4134	.278	21.6	210	131	.653	7.4	31.5	39.9	44.8	66.9	33.6	33.3	32.9	.3	
1988	4559	.298	21.2	227	141	.650	9.0	33.3	35.5	53.1	87.7	44.4	43.3	12.1	.2	
1989	4435	.307	20.9	234	146	.653	9.9	32.0	32.7	56.8	93.5	47.6	45.9	6.3	.2	
1990	3805	.302	20.7	237	151	.667	15.5	31.3	28.1	67.4	96.0	40.8	55.2	3.9	.2	
1991	4049	.322	21.3	228	150	.681	9.7	35.3	31.0	67.4	98.2	43.2	55.0	1.6	.1	
1992	4064	.334	20.8	234	155	.685	13.6	31.4	27.3	71.5	98.4	32.5	65.9	1.5	.1	
1993	4754	.360	21.0	235	162	.710	15.1	29.5	23.3	75.7	99.0	25.7	73.4	1.0		.2
1994	5481	.395	20.8	240	166	.715	13.7	36.4	23.9	74.7	99.6	23.2	76.5	.4		2.8
1995	5749	.380	20.5	244	168	.715	17.7	40.7	20.5	78.6	100.0	20.2	79.8			8.1
1996	5254	.400	20.8	243	179	.757	20.1	37.1	15.6	83.5	99.9		99.9		.1	10.4
1997	6224	.427	20.7	246	186	.775	13.6	42.9	15.6	84.0	100.0		100.0			11.0
1998	6555	.448	20.6	244	190	.801	19.0	43.8	13.9	85.6	100.0		100.0			14.3
1999	6822	.464	20.3	249	196	.809	17.2	46.9	13.0	86.7	100.0		100.0			15.7

TABLE 4 (CONTINUED)

VEHICLE SIZE AND DESIGN CHARACTERISTICS OF 1975 TO 1999 LIGHT DUTY VEHICLES

<---- MEASURED CHARACTERISTICS—><--------------- PERCENT OF VEHICLES EQUIPPED WITH ---------------->

MODEL YEAR	SALES (000)	FRAC	55/45 MPG	ENGINE CID	ENGINE HP	HP/ CID	DRIVETRAIN FRONT	DRIVETRAIN 4WD	TRANSMISSION MANUAL	TRANSMISSION LOCK	FUEL METERING FI	FUEL METERING TBI	FUEL METERING PORT	CARB	DSL	FOUR VALVE
Both																
1975	10224	1.000	15.3	293	137	.507	5.3	3.3	23.2		4.1		4.1	95.7	.2	
1976	12334	1.000	16.7	294	135	.493	4.6	4.8	20.9		2.5		2.5	97.3	.2	
1977	14123	1.000	17.7	287	136	.509	5.5	4.7	19.8		3.4		3.4	96.2	.4	
1978	14448	1.000	18.6	266	129	.525	7.4	6.6	23.0	5.2	3.9		3.9	95.2	.9	
1979	13882	1.000	18.7	252	124	.532	9.2	4.3	25.1	6.7	3.7		3.7	94.2	2.0	
1980	11306	1.000	22.5	198	104	.574	25.0	4.9	35.4	17.8	6.0	.6	5.2	89.7	4.3	
1981	10554	1.000	24.1	193	102	.579	31.0	4.0	34.1	33.0	7.5	2.2	5.1	86.7	5.9	
1982	9732	1.000	24.7	188	103	.593	37.0	4.6	32.8	47.8	13.8	7.9	5.8	80.6	5.6	
1983	10302	1.000	24.6	193	107	.599	37.0	8.1	31.5	52.1	22.1	14.7	7.3	75.2	2.7	
1984	14020	1.000	24.6	190	109	.618	42.1	8.2	28.5	52.8	30.6	18.6	11.4	67.6	1.8	
1985	14460	1.000	25.0	189	114	.649	47.8	9.3	27.0	54.5	43.0	23.9	16.0	56.1	.9	
1986	15365	1.000	25.7	180	114	.678	52.6	9.3	29.8	53.5	58.2	25.7	32.5	41.4	.4	1.1
1987	14865	1.000	25.9	175	118	.710	57.7	9.6	29.1	55.4	71.3	31.4	39.9	28.4	.3	4.0
1988	15295	1.000	25.9	180	123	.726	60.0	10.5	27.6	62.2	84.9	34.3	50.6	15.0	.1	7.3
1989	14453	1.000	25.4	185	129	.743	60.2	10.5	24.6	65.5	91.2	33.9	57.3	8.7	.1	8.9
1990	12615	1.000	25.2	185	135	.781	63.8	10.1	22.2	71.2	97.8	27.0	70.8	2.1	.1	17.9
1991	12573	1.000	25.4	184	138	.796	59.6	12.3	23.9	71.6	99.3	28.7	70.6	.6	.1	19.1
1992	12172	1.000	24.9	191	145	.807	58.4	11.2	20.6	74.8	99.4	17.8	81.6	.5	.1	19.8
1993	13211	1.000	25.1	191	147	.809	59.9	11.4	19.8	76.5	99.7	14.6	85.0	.3		21.1
1994	13883	1.000	24.6	196	152	.817	56.4	14.8	19.1	77.5	99.9	12.2	87.7	.1		24.7
1995	15145	1.000	24.7	196	158	.857	57.6	16.2	17.8	80.7	100.0	8.4	91.6			35.4
1996	13147	1.000	24.8	197	164	.878	60.0	15.7	15.2	83.5	99.9	.7	99.3		.1	37.9
1997	14571	1.000	24.5	199	169	.889	55.4	19.3	14.4	85.0	99.9	.5	99.5		.1	37.6
1998	14633	1.000	24.4	200	173	.907	56.7	20.8	13.8	84.6	99.8	.1	99.7		.2	38.9
1999	14699	1.000	23.8	206	180	.913	53.4	23.1	13.4	86.3	99.8		99.8		.2	39.6

Displacement by Number of Cylinders

Passenger Cars

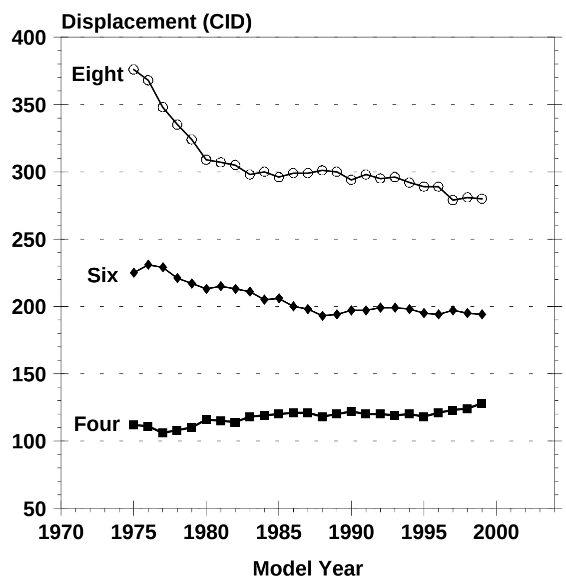

Figure 17

Displacement by Number of Cylinders

Light Duty Trucks

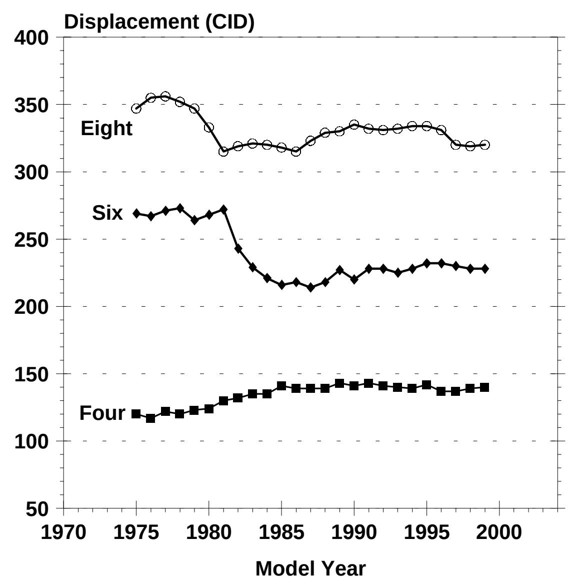

Figure 18

Table 5

Car and Light Truck Engine Characteristics - 1999			
Vehicle Type	**Horsepower (HP)**	**Displacement (CID)**	**HP/CID**
Passenger Car	166	169	1.00
Light Truck	196	249	0.81

Because of the differences in specific power, for model-year 1999, truck engines average about 18 percent more horsepower but nearly 50 percent greater displacement, compared to the average passenger car engine.

Figures 17 and 18 show cubic-inch displacement (CID) *by number of cylinders* for cars and light trucks; Figures 19 and 20 normalize this data and show CID *per cylinder* for both vehicle types. For both cars and light trucks, displacement of six- and

Displacement Per Engine Cylinder
Passenger Cars

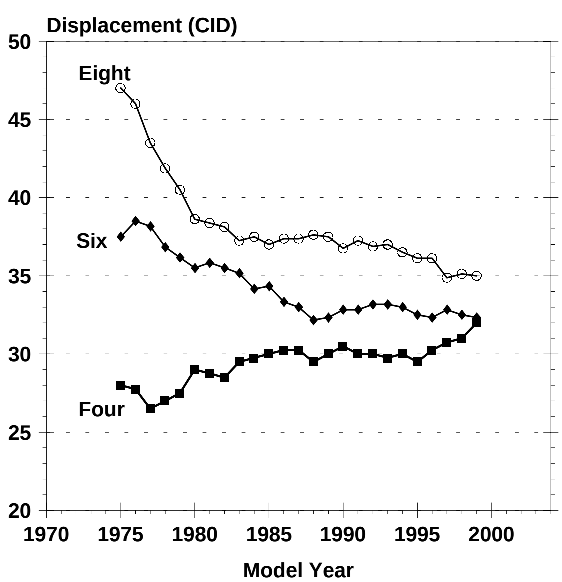

Figure 19

Displacement per Engine Cylinder
Light Duty Trucks

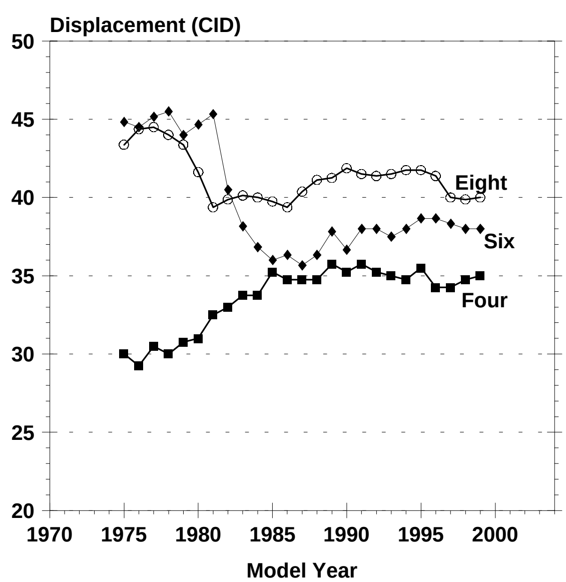

Figure 20

eight-cylinder engines has decreased, but displacement of four-cylinder engines has increased. Most of these changes occurred between 1975 and 1985 when, for example, eight-cylinder car engine CID decreased about 20 percent, i.e., from 376 to 296 CID. Similarly, six-cylinder car engines decreased from 225 CID in 1975 to 200 in 1986 and 194 this year. Conversely, four-cylinder passenger engine displacement increased from 112 CID in 1975 to 120 CID in 1985.

CID per cylinder, thus, has converged for cars from a range of about 27 to 47 CID per cylinder in 1975 to a range of about 32 to 35 CID per cylinder this year. Similarly, CID per cylinder for trucks remains somewhat higher than that for cars but has converged from a range of about 30 to 45 CID per cylinder to a range of 35 to 40.

Figures 21 and 22 indicate that horsepower has increased for four-, six-, and eight-cylinder engines for both vehicle types. Eight-cylinder car engines, for example, now attain 242 HP, compared to 167 HP in MY75. This represents an increase of nearly 45 percent. By comparison, six-cylinder engines have achieved at least 167 HP every year since MY95.

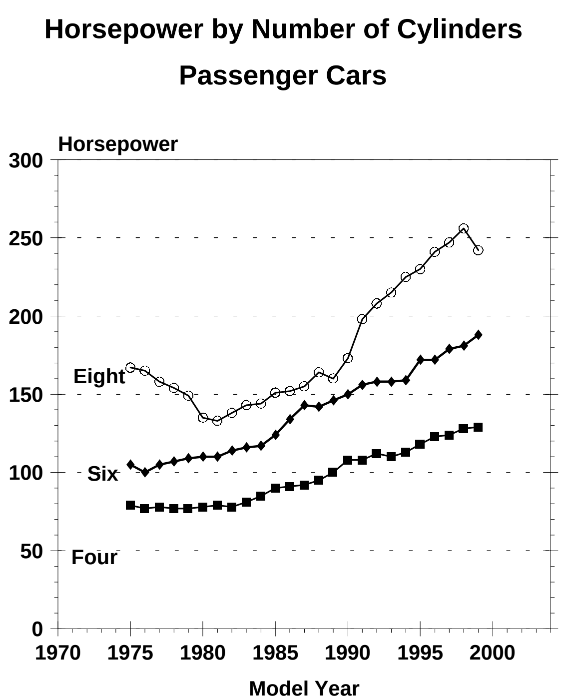

Figure 21

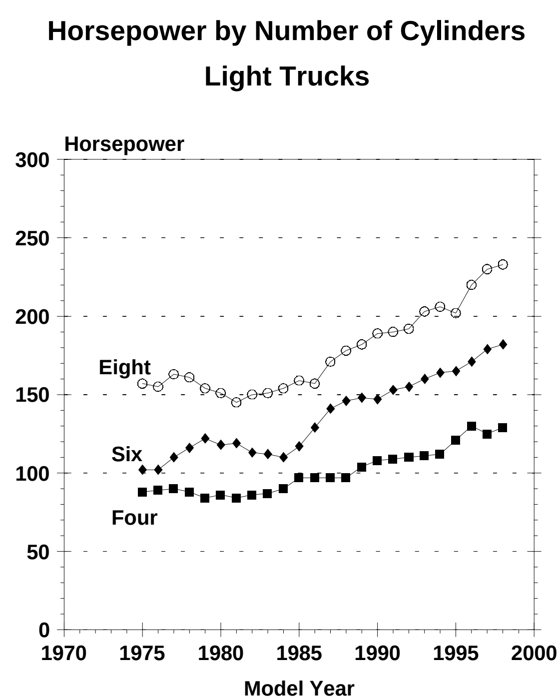

Figure 22

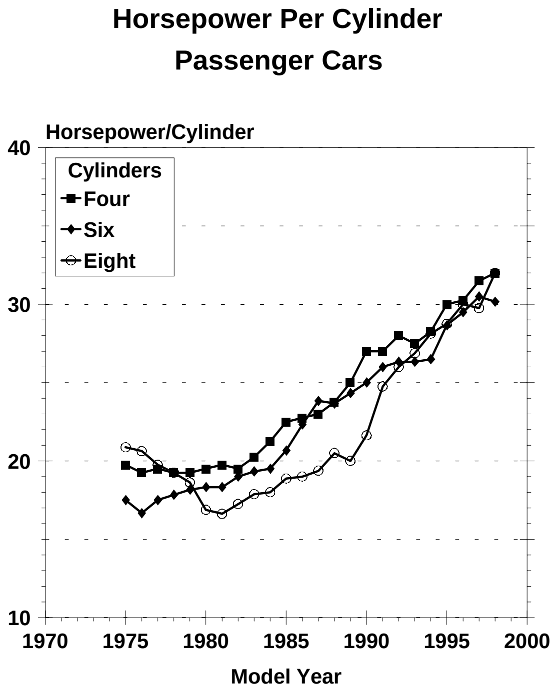

Figure 23

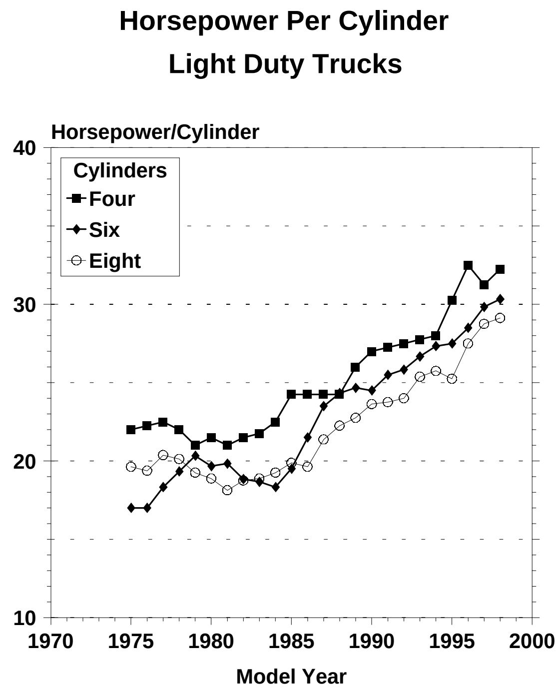

Figure 24

On a percentage basis, an even greater increase has occurred for six-cylinder engines which, for MY99, are expected to average 188 HP compared to 105 in MY75. Six-cylinder engines thus will achieve higher horsepower this year than eight-cylinder ones did every year from 1975 to 1990. Similarly, for MY99, four-cylinder car engines will average 129 HP, or more than the six-cylinder engines did for any year between 1975 and 1985.

As shown in Figures 23 and 24, horsepower-per-cylinder has changed at very similar rates for four-, six-, and eight-cylinder engines. Between 1975 and 1986, horsepower-per-cylinder for both cars and trucks at this level of stratification changed very little. Since then, for both vehicle types, it has increased considerably and is now a nominal 50 percent higher than it was a decade ago.

Specific power (HP/CID) has also changed at slightly different rates for the engine sizes and types presented in Figures 25 and 26. Since 1975, for both cars and trucks, four-cylinder engines achieved higher specific power values than their six- and eight-cylinder counterparts. For MY99, six- and eight-cylinder car engines achieved significantly higher specific power than four-cylinder car engines did a decade ago.

Specific power improvement for trucks has lagged that for cars and is currently behind by about four or five years. For example, four-cylinder truck engines currently have a specific power rating of .95 HP/CID, a value four-cylinder car engines surpassed in MY94 when they first averaged .96 HP/CID.

Figures 27 and 28 compare sales fractions by four-, six- and eight-cylinder engines for cars and light trucks. For purposes of this analysis, two-, three-, five-, ten- and twelve-cylinder car engines are combined into a category labeled ‘other’. Even on a combined basis, these ‘other’ engines have accounted for a very small percentage of the cars built each year since 1975.

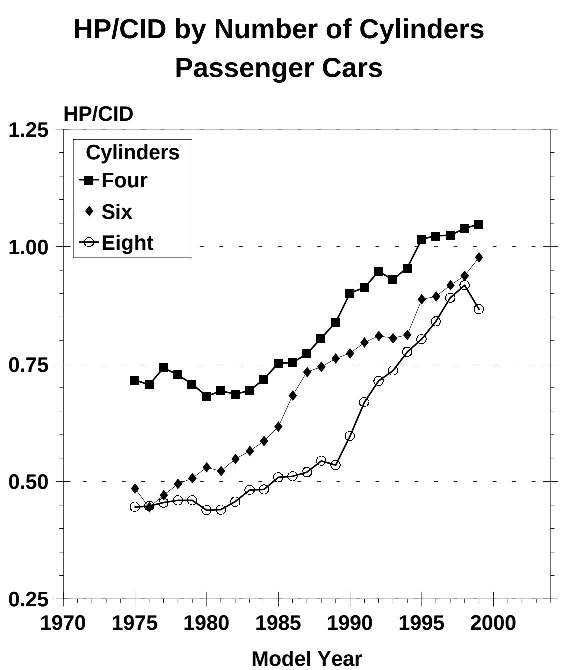

Figure 25

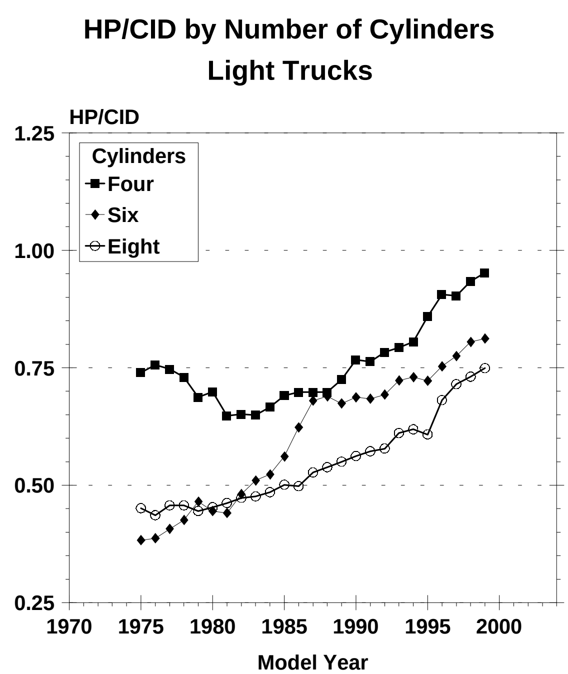

Figure 26

The sales fraction for eight-cylinder engines has dropped for cars from nearly 60 percent in 1975, to about 20 percent in 1981, to the 10-percent level in 1990 where it has remained. Most of this decrease occurred between 1975 and 1980. Similarly, the sales fraction for eight-cylinder truck engines dropped from 75 percent in 1975 to about 35 percent in 1983 and about 19 percent in 1991. Since then, however, the sales fraction of eight-cylinder engines has nearly doubled and is projected to be back at about 35 percent this year.

The sales fraction of six-cylinder car engines remained within a relatively narrow range (i.e., about 18, plus or minus two percent) between 1975 and 1979. Since then, their sales fraction has more than doubled and is projected to be about 40 percent this year. From 1975 to 1992, a similar trend occurred for six-cylinder truck engines. Their sales fraction increased from less than 15 percent in 1975 to over 60 percent in 1992 but since then has dropped back to the 50-percent level.

Four-cylinder engines now account for more than 50 percent of MY99 cars but less than 15 percent of 1999 trucks (See Figures 27 and 28).

Sales Fraction by Number of Cylinders

Passenger Cars

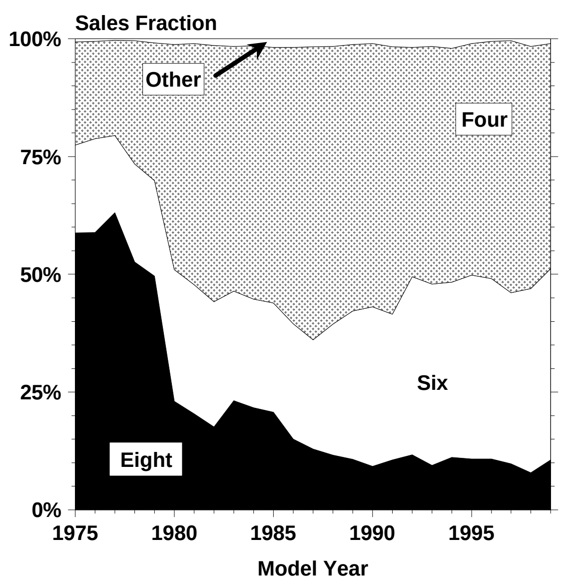

Figure 27

Sales Fraction by Number of Cylinders

Light Trucks

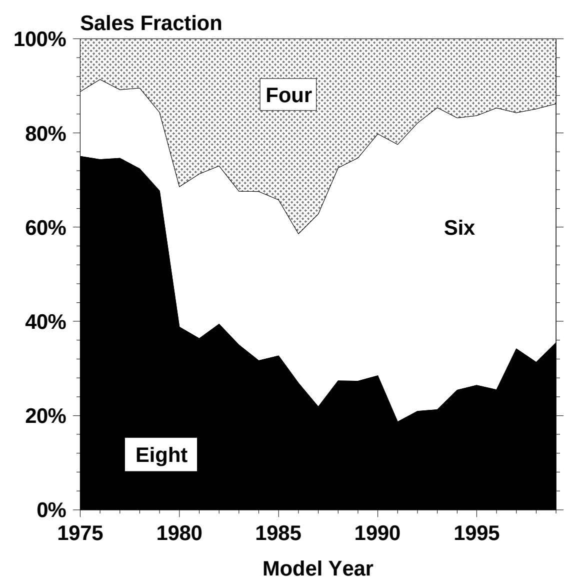

Figure 28

Passenger car engines have high values of HP per CID because not only HP per CID is improving, but also the fraction of the higher specific-power engines is increasing. Figures 29 and 30 show HP/CID for engines with 2-, 3-, and 4-valve-per-cylinder cylinder-head configurations for cars and trucks. Trucks with the same cylinder-head configuration have lower specific power than do the corresponding passenger car engines.

Figures 31 and 32 show the market share by number of valves per cylinder for cars and trucks. The introduction and use of four-valve engines for light trucks has trailed that of cars. Almost 85 percent of all truck engines still have two valves per cylinder, but the market share of 4-valve-per-cylinder passenger car engines is now over the 60-percent mark.

The use of four valves per cylinder in passenger car engines grew rapidly between 1987 and 1995, but its rate of growth has been much slower since then. The increased use of this engine technology belongs in the same category as successful technologies like port fuel injection, front-wheel drive, and the lockup 4-speed transmission (see Figure 33). In contrast, 3-valve-per-cylinder engines can be grouped with the less successful technologies like throttle body fuel injection (TBI) and lockup 3-speed (L3) transmissions (See Figure 34).

HP/CID by Number of Valves Per Cylinder

Passenger Cars

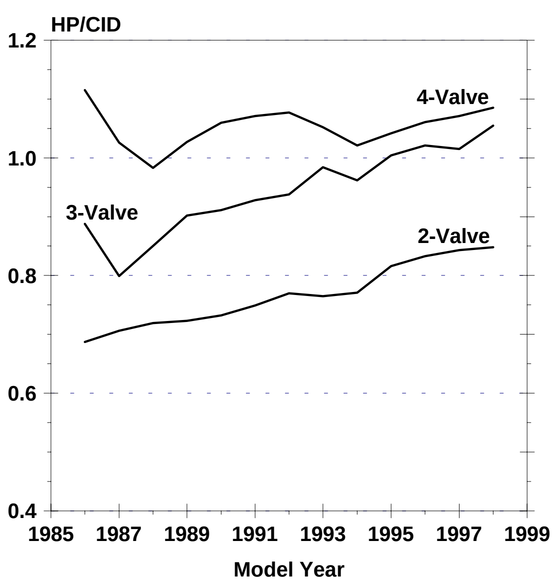

Figure 29

HP/CID by Number of Valves Per Cylinder

Light Duty Trucks

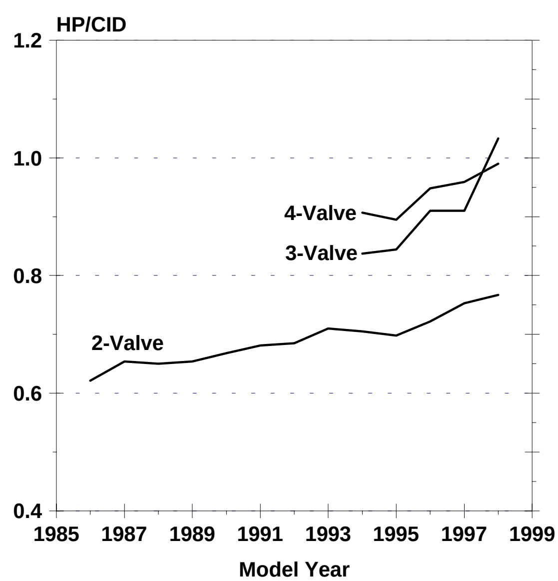

Figure 30

Number of Valves Per Cylinder
Passenger Cars

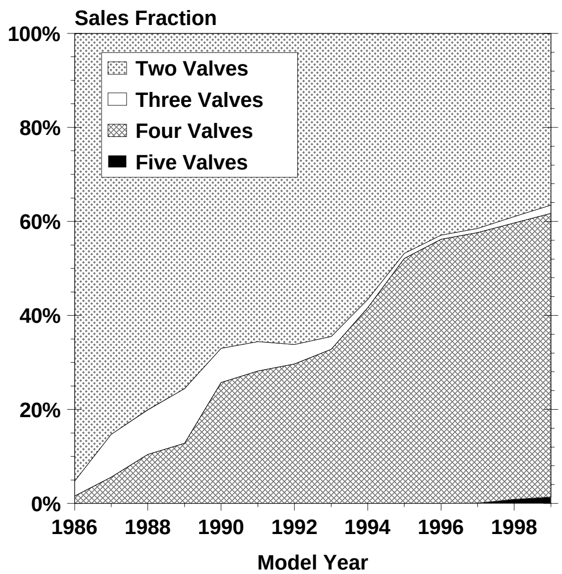

Figure 31

Number of Valves Per Cylinder
Light Duty Trucks

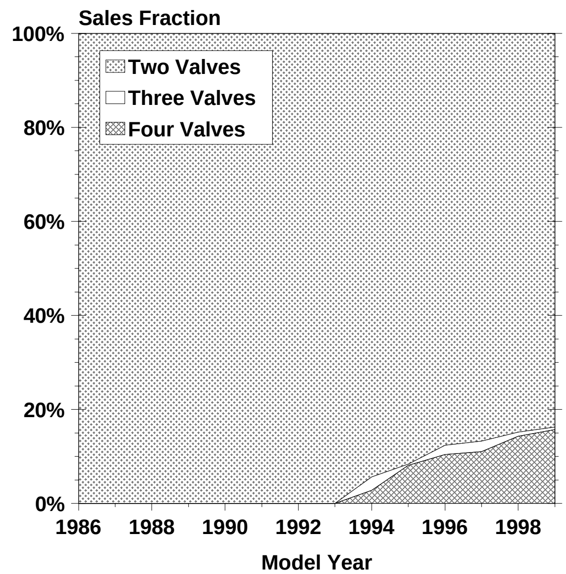

Figure 32

Passenger Car Technology Penetration
Years After First Significant Use

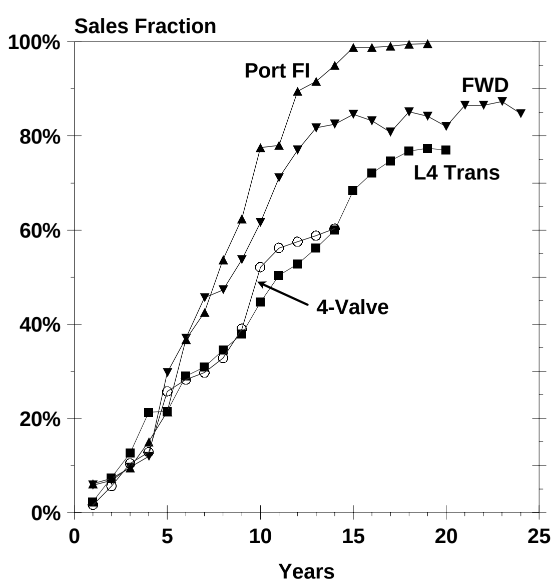

Figure 33

Passenger Car Technology Penetration
Years After First Significant Use

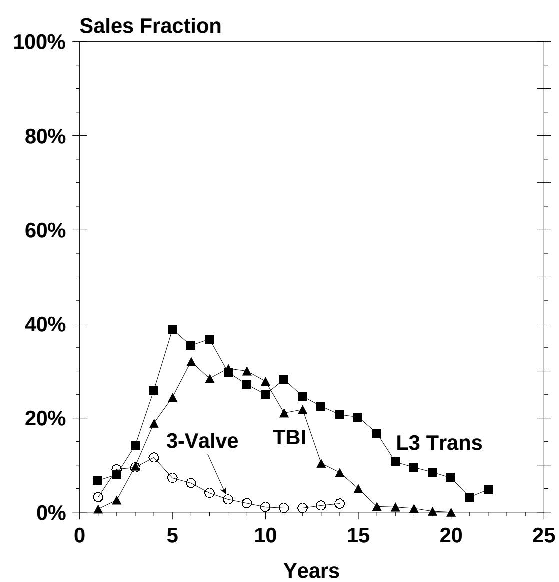

Figure 34

Figures 35 and 36 compare the sales fractions by transmission type and number of gears for cars and trucks, respectively. Manual transmission usage peaked slightly above 30 percent for cars in 1980 and has been below 15 percent since 1996. Similarly, it peaked at more than 50 percent that same year for trucks and has also dropped below 15 percent.

Two important changes have occurred for both vehicle types, the addition of a gear for both automatic and manual transmissions and, for the automatics, conversion to lockup torque converter transmissions. Both of these figures indicate that the L4 transmission is currently the predominant transmission type for both cars and trucks. Trucks have not lagged cars in the introduction of L4 transmissions. Where manual transmissions are used, the 5-speed (M5) transmission now predominates. The increasing trend in ton-MPG discussed earlier can be attributed to better vehicle design, including more efficient engines, better transmission design, and better matching of the engine and transmission.

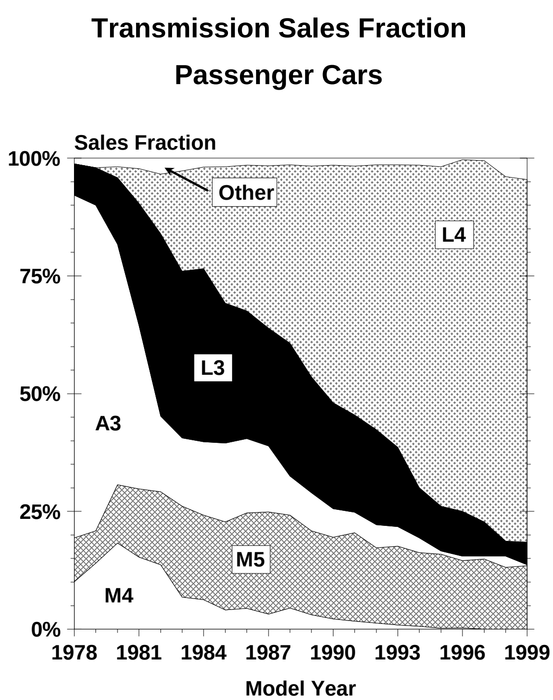

Figure 35

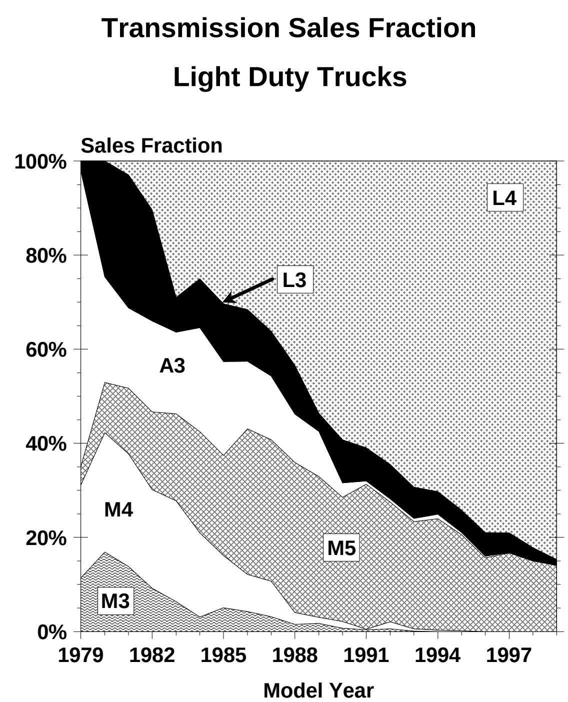

Figure 36

Passenger Car Ton-MPG

By Transmission and Number of Gears

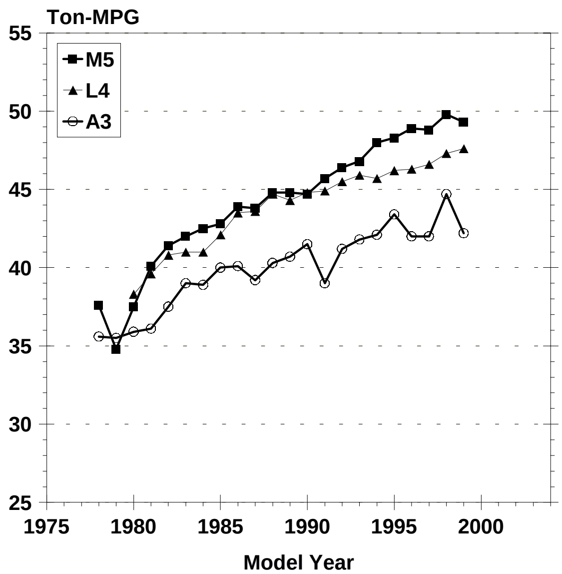

Figure 37

Light Truck Ton-MPG

By Transmission and Number of Gears

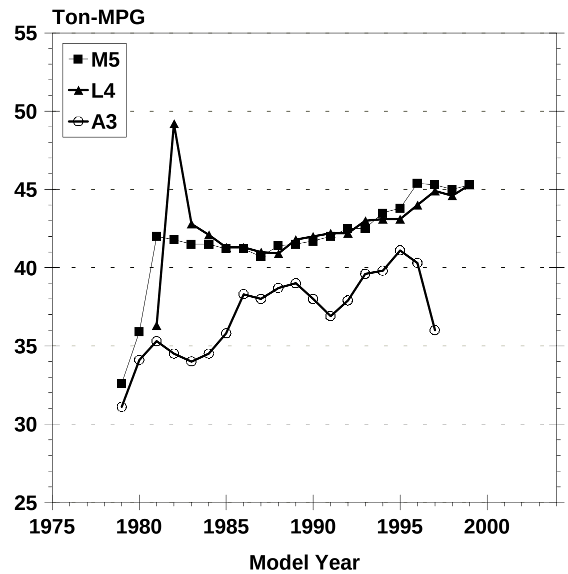

Figure 38

In recent years, trucks with L4 and M5 transmissions have achieved about the same ton-MPG; cars with M5 transmissions achieved about 2 ton-MPG more than their L4 counterparts.

Powertrains are matched to the load better when the engine operates closer to its best efficiency point more of the time. For many conventional engines, this point is approximately 2000 RPM and 2/3 of the maximum torque at that speed. One way to make the engine operate more closely to its best efficiency point is to increase the number of gears in the transmission and, for automatic transmissions, using a lockup torque converter.

Figures 37 and 38 indicate that ton-MPG improves when more transmission gears are added and lockup torque converters used. For both cars and light trucks, ton-MPG improves by about 10 percent with the addition of a gear and a lockup torque converter. It should be noted that between 1981 and 1982 there was a sharp increase in ton-MPG for light trucks with L4 converters. As the data in Appendix E indicates, diesel engines were used in about 44 percent of the 1982 trucks with this transmission type, compared to about ten percent the next year, and about five percent in 1984.

Front, Rear and Four Wheel Drive Usage

Passenger Cars

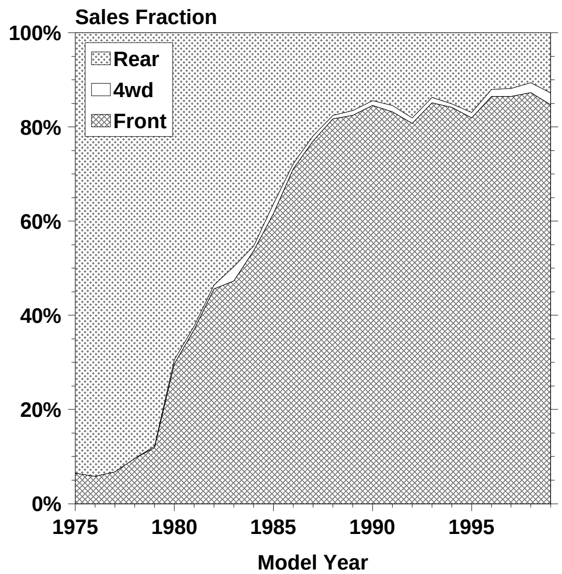

Figure 39

Front, Rear and Four Wheel Drive Usage

Light Duty Trucks

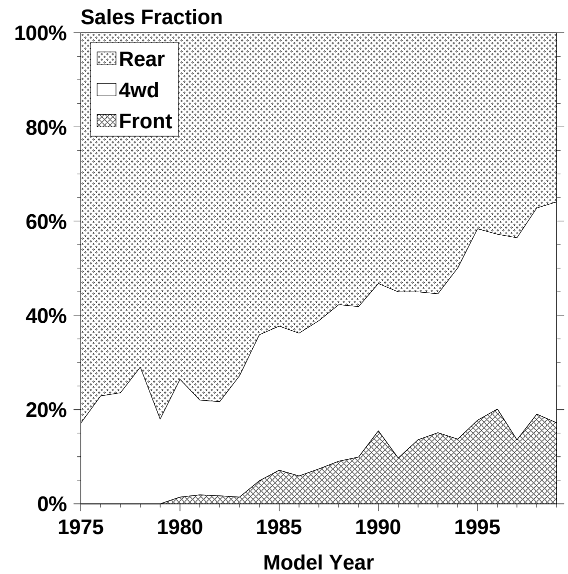

Figure 40

In Figures 39 and 40, the differences and changes in drivetrain configuration between cars and trucks are apparent. Prior to 1978, less than ten percent of cars used front-wheel drive with almost all of the remainder rear drive. For the past dozen years, more than 80 percent of the cars have used front-wheel drive. Rear-wheel drive accounted for nearly 95 percent of the 1975 cars; by 1984 its sales fraction dropped below 50 percent; and since 1988 it has stayed below 20 percent. For all of the years shown, four-wheel drive has been used in only a few percent of the cars.

Drivetrain usage for trucks has also changed substantially. Prior to 1994, over half of the trucks used rear-wheel drive, but only about a third of the 1999 trucks will. By comparison, five out of six 1975 trucks used rear-wheel drive. Four-wheel drive usage in trucks has grown from less than 18 percent in 1975 to almost half this year. Front-wheel drive in trucks remained below 5 percent through 1984, first exceeded 20 percent in 1996, but has dropped slightly since then. This technology is now used extensively in mid-sized vans, but not at all in pickups and relatively little in SUVs.

IV. Trends by Market Segment

Figures 41 and 42 show that domestic trucks and Asian cars have achieved the largest growth in both sales and sales fraction since 1975 with much of this growth coming at the expense of domestic cars. The market share of domestic cars has dropped from about 65 percent in 1975 to 31 percent this year. At the same time, the market share of Asian cars and domestic trucks has both doubled, from 8 to 19 and from 17 to 36 percent, respectively.

For the past three years, sales of domestic trucks have exceeded those of domestic cars. Total sales of domestic light-duty trucks are projected to be more than three times higher this year than they were in 1975, but domestic car production will be less than two-thirds of what it was in 1975. Similarly, sales of imported vehicles are projected to be almost three times higher in 1999 than they were in 1975. More than three times as many Asian cars will be sold in 1999 as in 1975, and imported truck sales are projected to be higher by a factor of more than five, but sales of European cars are projected to be about the same this year as they were in 1975.

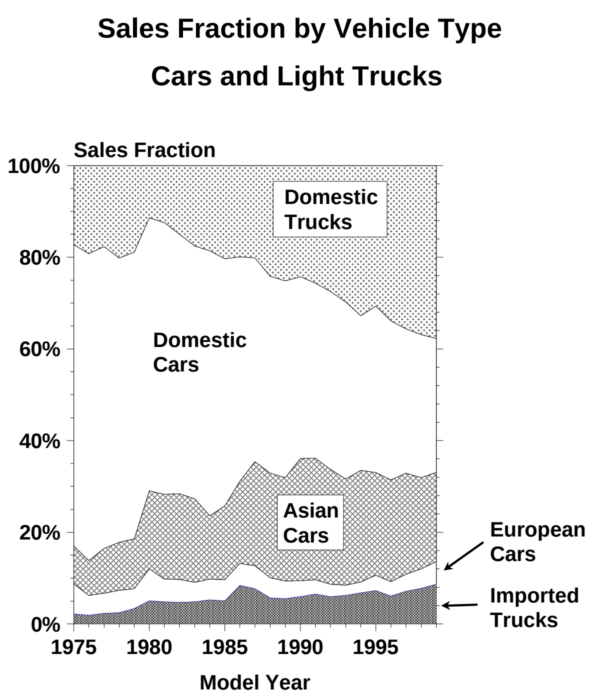

Figure 41

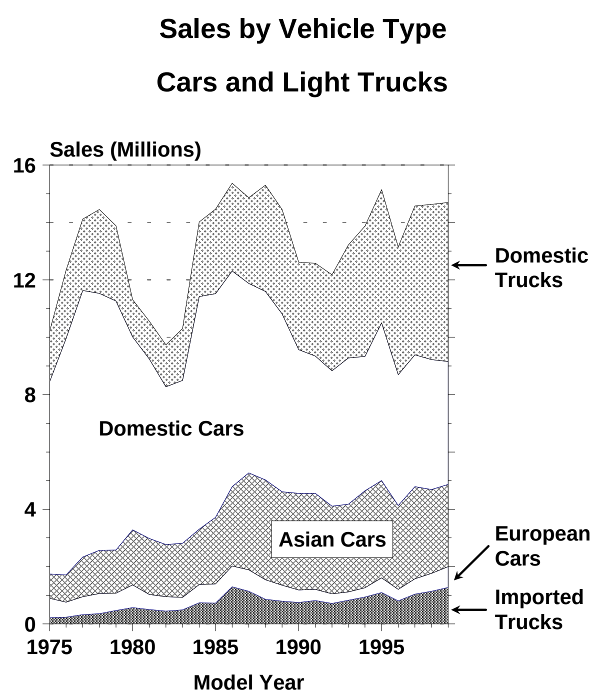

Figure 42

Figure 43 compares average MPG for domestic, European, and Asian cars. Similar data for domestic and imported trucks is shown in Figure 44. Asian cars have always had higher MPG than their domestic counterparts. Through 1985, European cars had higher MPG than domestic ones. Since 1986, however, domestics have achieved higher MPG than European cars.

Average car MPG for all three of these segments has changed very little since 1990, particularly when compared to the changes which occurred in the late 1970's and early 1980's. For example, domestic car MPG increased over 10 MPG between 1975 and 1985 but has stayed between 25.8 and 27.8 MPG since then.

The trend for domestic light trucks is similar. Their average MPG increased over 6 MPG or almost 50 percent between 1975 and 1985 but has been a nominal 20 MPG since then. Imported truck MPG peaked at 26.6 MPG in 1984 and has now declined to 23.2 MPG. As shown in Figure 45, the gap between imported and domestic combined car and truck MPG has remained at about 5 or 6 MPG for over a decade, compared to a much larger difference in 1975.

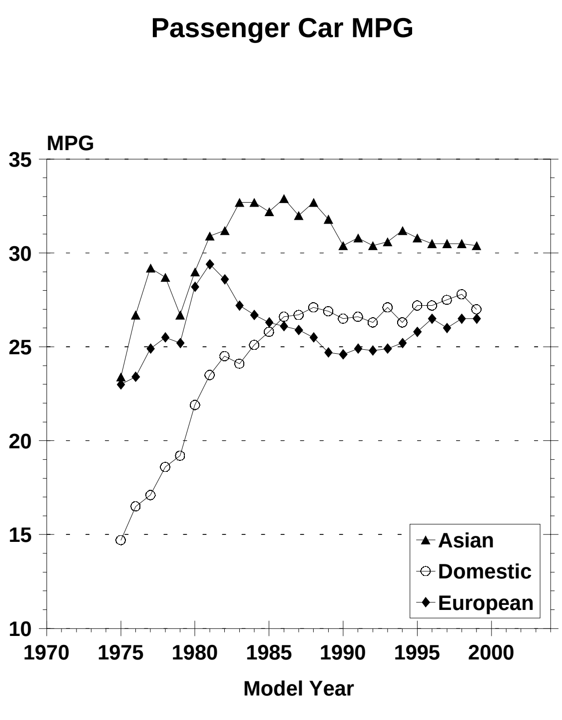

Figure 43

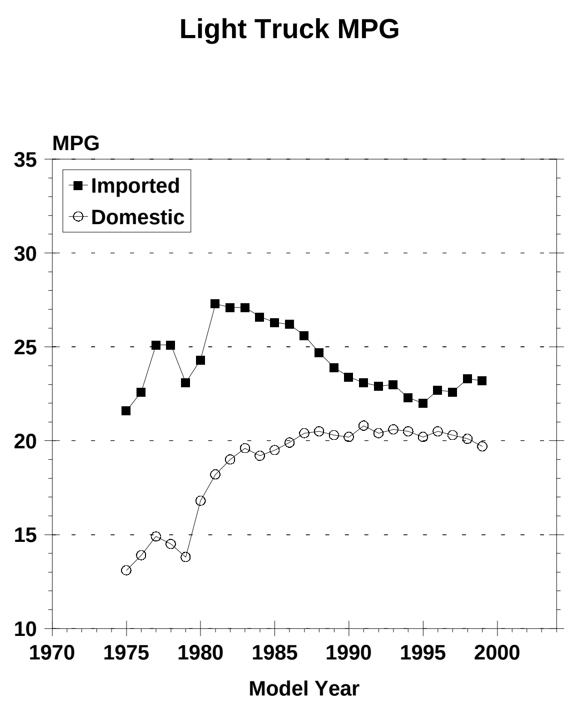

Figure 44

Car and Light Truck MPG

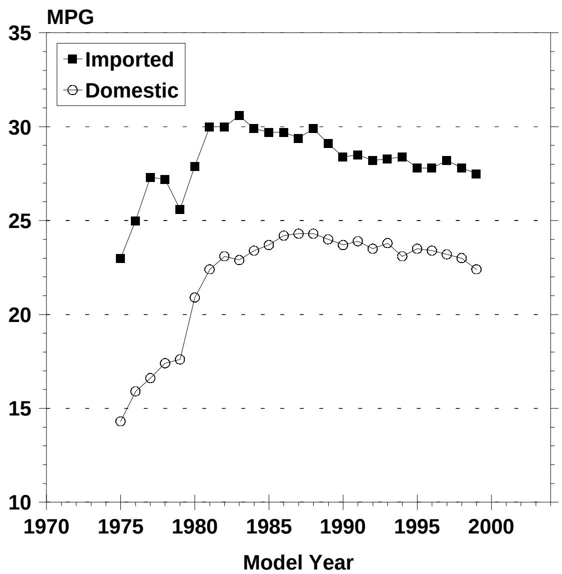

Figure 45

Passenger Car Interior Volume

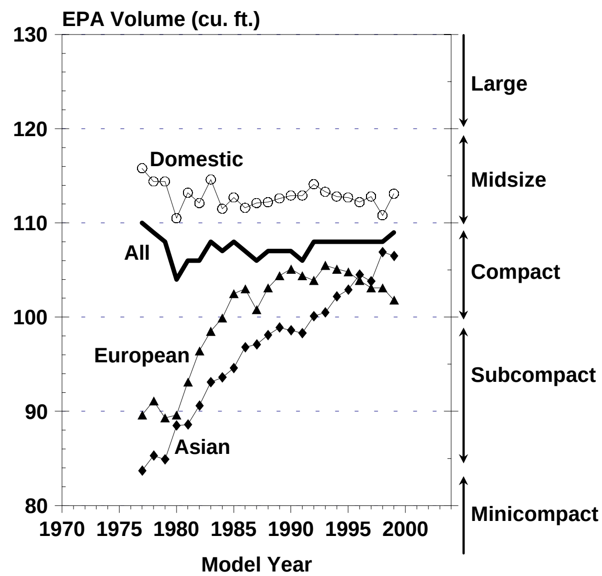

Figure 46

Figure 46 compares interior volume for domestic, European, and Asian cars. Through 1980, interior volume for European cars remained below 90 cu. ft.; between then and 1989, it increased over 16 percent to 105 cu. ft. and has since decreased to 102 cu. ft. Asian cars, with just a couple of minor exceptions, have increased their interior volume every year since 1978. By comparison, domestic car interior volume has been relatively stable, as has the overall average for all passenger cars.

Vehicle performance, as measured by estimated 0 to 60 acceleration time, has changed at remarkably consistent rates for domestic, European, and Asian cars and also for domestic and European trucks. European cars have typically achieved about one second faster 0 to 60 time than their domestic and Asian counterparts. Through 1984, estimated 0 to 60 time remained at a relatively constant 14 to 15 seconds for all of the market segments shown in Figure 47 and 48. During the past thirteen years, this performance metric has dropped by about four or five seconds for cars, and by about three or four seconds for trucks.

Passenger Car 0 to 60 Time

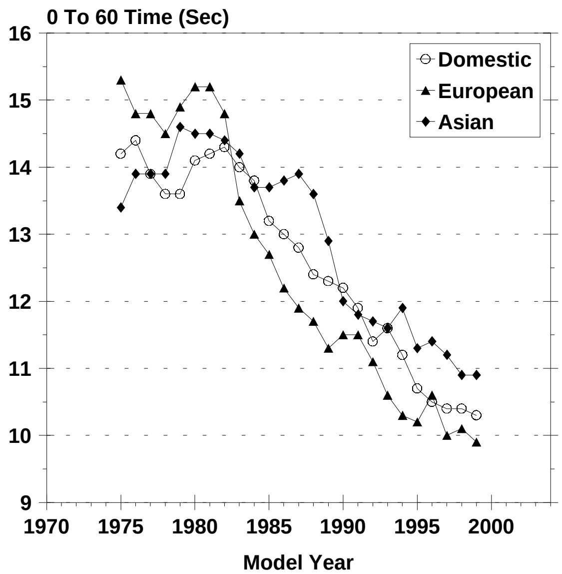

Figure 47

Light Truck 0 to 60 Time

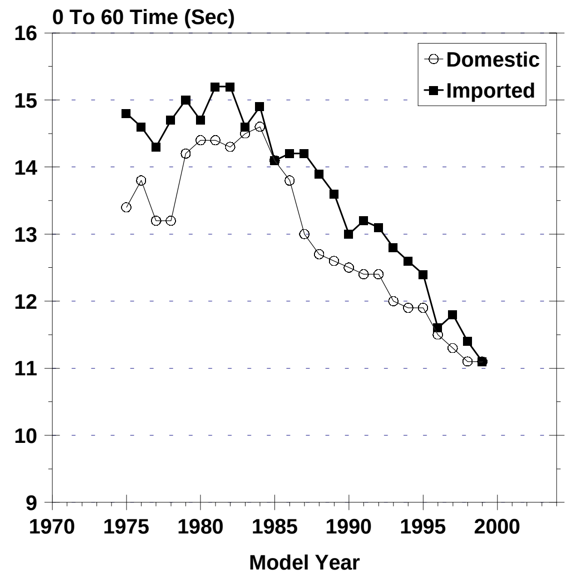

Figure 48

Passenger Car Inertia Weight

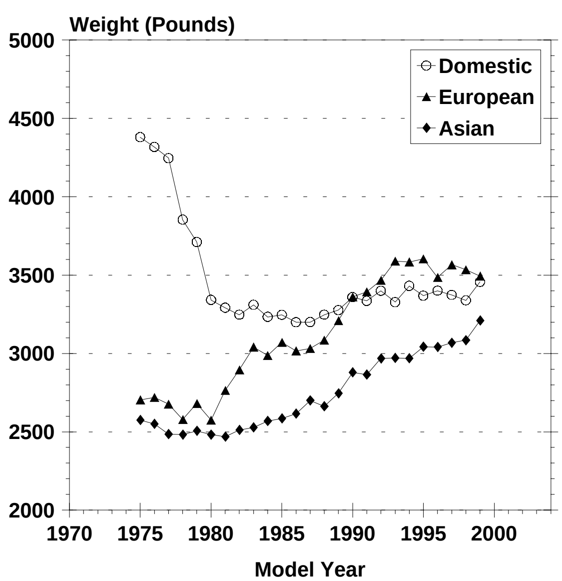

Figure 49

Light Duty Truck Inertia Weight

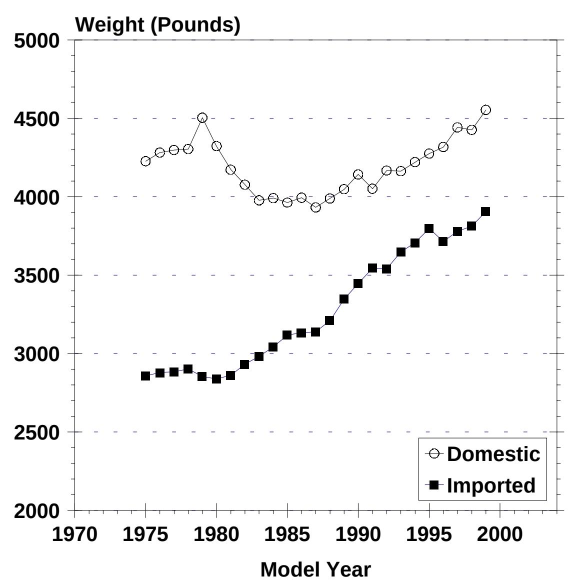

Figure 50

Passenger Car Ton-MPG

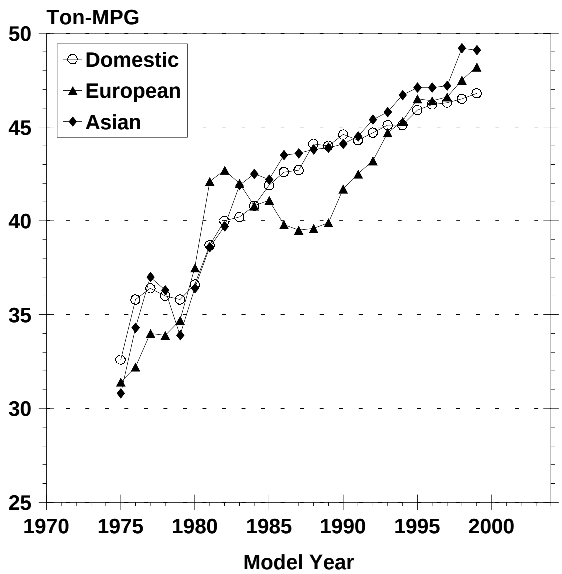

Figure 51

Light Duty Truck Ton-MPG

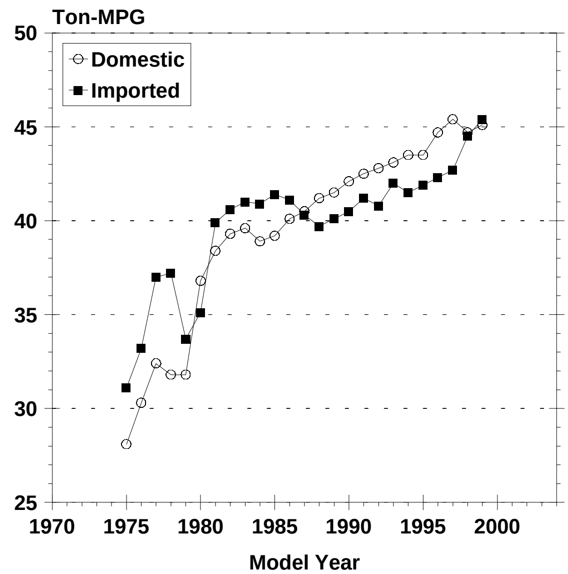

Figure 52

Figures 49 and 50 compare inertia weight for the same market segments as the preceding two figures. Inertia weight for domestic cars dropped over a thousand pounds between 1975 and 1984 but has increased about 200 pounds since then. Conversely, inertia weight of European cars increased by over 350 pounds (i.e., from about 2700 to 3070 pounds) between 1975 and 1985 and by over another 500 pounds since then. Between 1975 and 1985, inertia weight for Asian cars remained at a nominal 2500 pounds but has since increased to over 3200 pounds.

As indicated by Figure 50, there have been substantial increases in inertia weight for both domestic and imported trucks, particularly since the mid-1980's. Between 1984 and this year, domestic truck inertia weight has increased by over 400 pounds and imported truck inertia weight by over 800.

The trend toward increasing ton-MPG, discussed earlier, persists for the five market segments shown in Figures 51 and 52. Domestic, European, and Asian cars not only have had similar ton-MPG trends but also the same approximate ton-MPG values over a relatively long period of time. The same observations apply to domestic and imported light trucks.

Passenger Car Specific Power

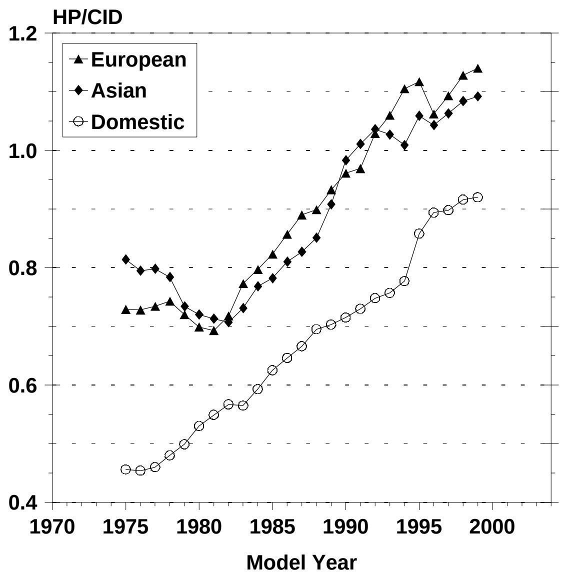

Figure 53

Light Duty Truck Specific Power

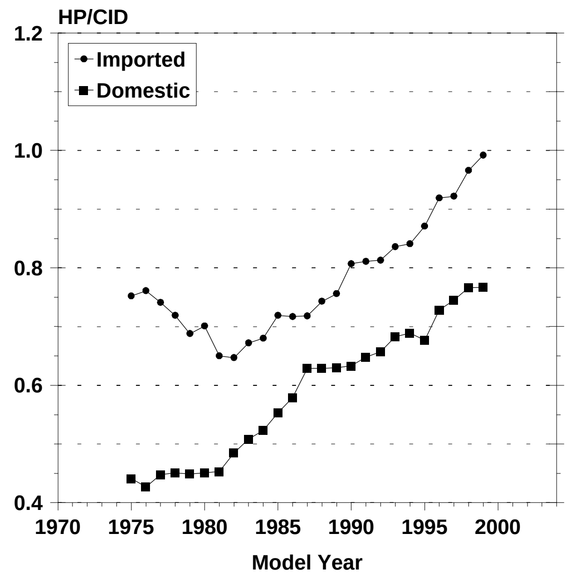

Figure 54

The trend toward higher specific power (HP/CID), also discussed earlier, persists for domestic, European, and Asian cars and domestic and imported trucks (see Figures 53 and 54). European and Asian cars now achieve about 1.1 HP/CID and the domestics slightly better than .9 HP/CID. Similarly, imported trucks will achieve about 1.0 HP/CID this year compared to less than .8 for domestic trucks. The improvement of specific power for domestic vehicles has always trailed that of their import counterparts by about a decade with the imported vehicles achieving at least .2 HP/CID more than the domestics.

Table 6 compares technology usage for MY99 for domestic, European, and Asian cars and domestic and imported trucks. The trend noted above towards higher specific power for European and Asian cars and imported trucks is consistent with their greater use of four valve per cylinder engines than the domestics. For MY99, drive train usage for domestic and imported trucks is remarkably consistent. A nominal 50 percent of both vehicle types are projected to use four-wheel drive and about 20 percent front-wheel drive. Conversely 94 percent of Asian cars will use front-wheel drive, compared to 85 percent of the domestics and less than half of the European cars. The percentage of domestic cars and trucks that are projected to have manual transmissions is significantly less than that of the their imported counterparts.

Table 6

MY99 Technology Usage
(Percent of Vehicles)

	Front Wheel Drive	Four Wheel Drive	Manual Trans-mission	Four Valves per Cylinder
Domestic Cars	85	0	9	37
European Cars	46	12	34	50
Asian Cars	94	4	16	98
Domestic Trucks	17	46	11	1
Imported Trucks	19	52	24	81

Figures 55 to 63 compare the sales and sales fractions of small, midsize, and large domestic, European, and Asian cars. In 1975, approximately one-fourth of the domestic cars were small; another fourth, large; and about half, midsize. Since then, the sales fractions of domestic small, midsize, and large cars have fluctuated five to ten percent. For example, large cars accounted for 26 percent of the domestics in 1975, 15 to 18 percent from 1979 to 1981, then increased their relative market share to 21 percent in 1985, dropped to around 20 percent for the next few years, but reached the 27 percent mark in 1994.

The changes which have occurred in the relative market shares of small, midsize, and large Asian and European cars are much more substantial than that of the domestics. In 1975, all of the Asian cars were classified as small, compared to about half this year. For MY99, the sales fraction of midsize Asian cars has increased to the point where they account for over 45 percent of the Asian cars, compared to about 25 percent in 1997, and less than 10 percent in 1991. The trend for European cars is very similar. The sales fraction of small European cars has dropped from nearly 95 percent in 1975 to about 60 percent this year, while the midsize car sales fraction has increased from 5 percent in 1975 to nearly 40 percent the past two years.

Domestic Car Sales Fraction by Vehicle Size

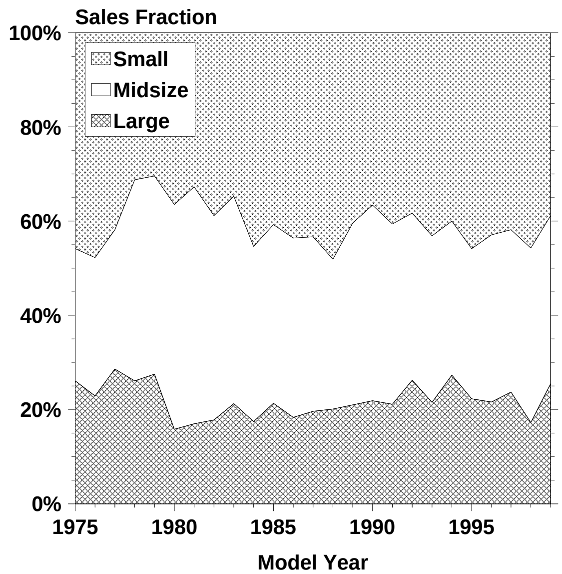

Figure 55

Domestic Car Sales by Vehicle Size

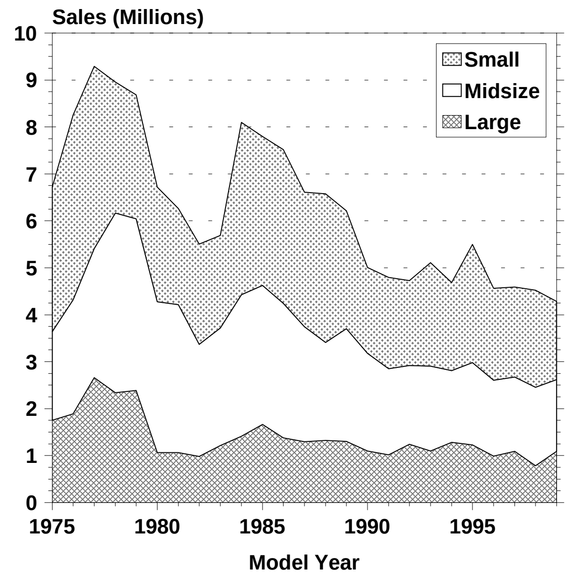

Figure 56

European Car Sales Fraction by Vehicle Size

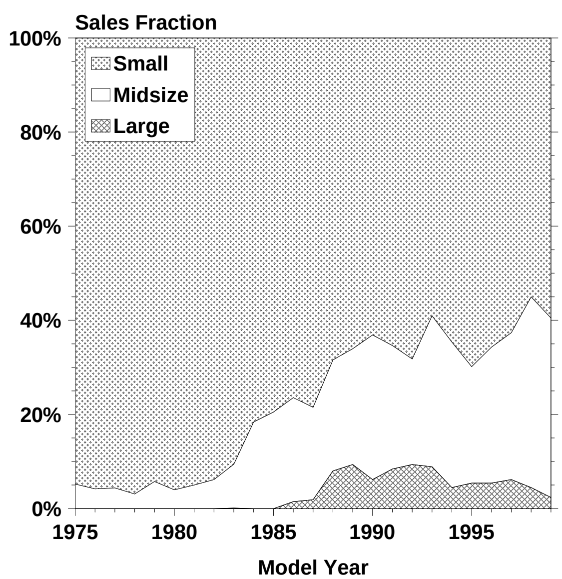

Figure 57

European Car Sales by Vehicle Size

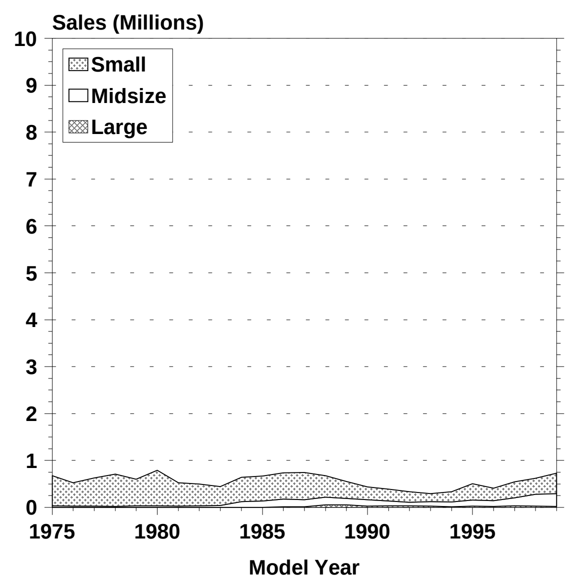

Figure 58

Asian Car Sales Fraction by Vehicle Size

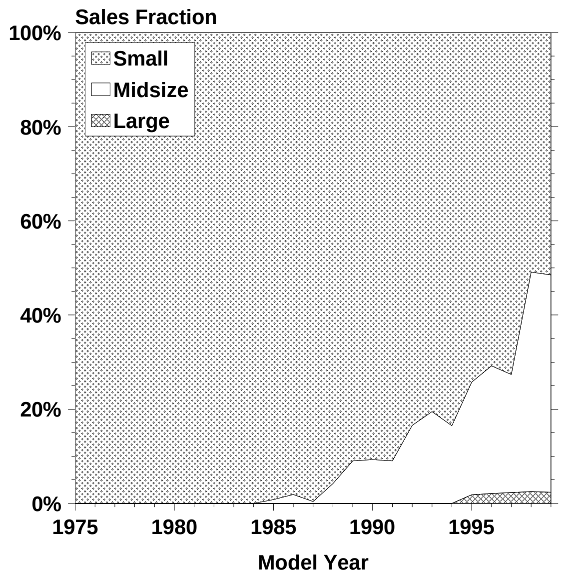

Figure 59

Asian Car Sales by Vehicle Size

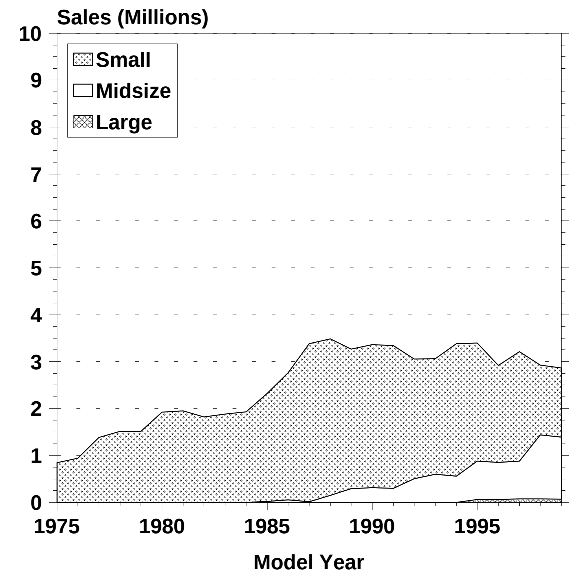

Figure 60

As shown in Figure 56, sales of large domestic cars reached the 2.7 million level, dropped to about a million in 1980, and have been relatively constant since then. Midsize domestic sales peaked at 3.8 million in 1978 and have been less than half that amount since 1991. Sales of small domestic cars almost reached the 4 million mark in 1977, then declined, and have not exceeded 2.5 million in nearly a decade.

Sales of European cars have been less than 750,000 per year for all of the years shown in Figure 58. Large cars have never accounted for more than 10 percent of the European cars; their annual sales reached a nominal 50,000 per year in 1988 and 1989. Sales of midsize European cars remained below 50,000 per year from 1975 to 1984, increased to over 100,000 in 1984, and have been over 250,000 per year for the past two years. Annual sales of small European cars exceeded 500,000 through 1987, but have not been that high since then.

Sales of small Asian cars (see Figure 60) increased from 1.5 million per year in 1975 to over a nominal 3 million per year from 1987 to 1991, but have since dropped to half that level the

Domestic Truck Sales Fraction by Vehicle Size

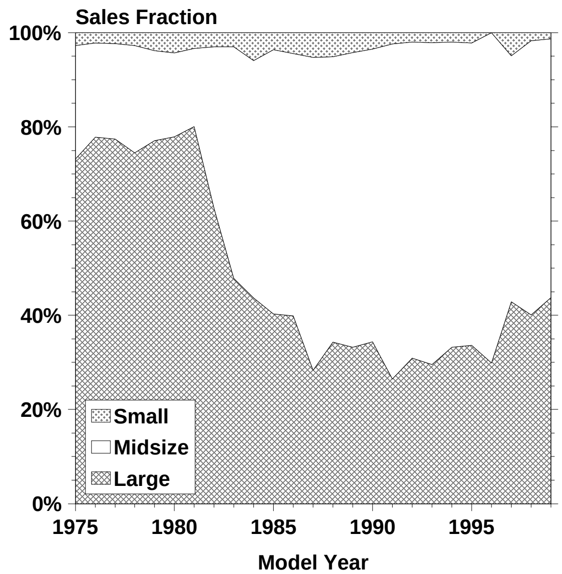

Figure 61

Domestic Truck Sales by Vehicle Size

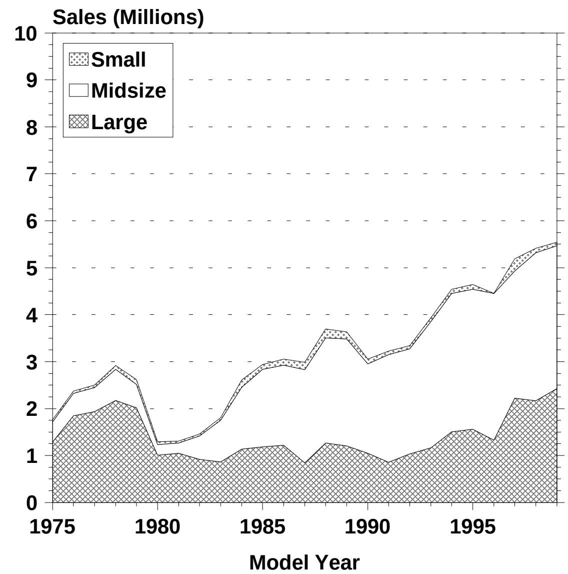

Figure 62

past two years. Annual sales of midsize Asian cars have increased by nearly two orders of magnitude, from 18,000 in 1975 to 500,000 in 1992 and have been over 1.3 million the past two years. Large Asian cars, first introduced in the mid-80's, have accounted for more than 60,000 vehicle sales per year since 1995.

Figures 61 and 62 make a similar comparison of sales fractions for small, midsize, and large domestic and imported trucks. From 1975 to 1981, large trucks accounted for nearly three-fourths or more of the domestic trucks, compared to about 43 percent this year. A corresponding change has occurred for midsize domestic trucks; their sales fraction has more than doubled and has increased from about 24 percent in 1975 to more than 50 percent every year since 1984. Small trucks, on the other hand, have never accounted for more than a few percent of the domestics.

Annual sales of large domestic trucks remained above 2 million from 1975 to 1979, dropped by half the following year, then remained constant through the mid-1990's, but have been above the 3 million level the past three years. Sales of midsize domestic trucks passed the 1 million per year level in 1984 and have been a nominal 3 million per year since 1994.

Imported Truck Sales Fraction by Vehicle Size

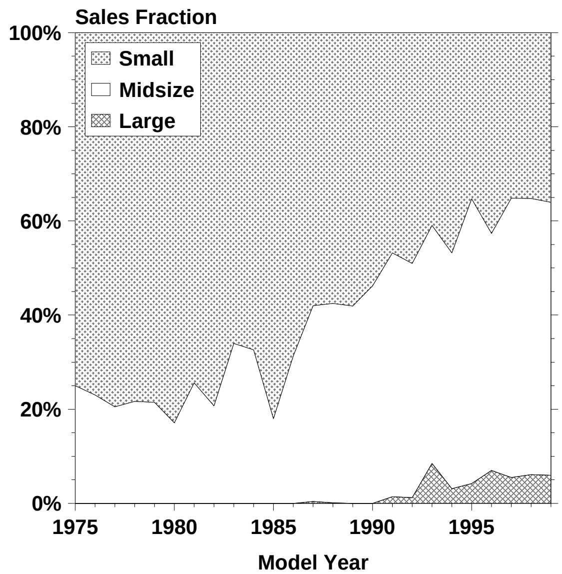

Figure 63

Imported Truck Sales by Vehicle Size

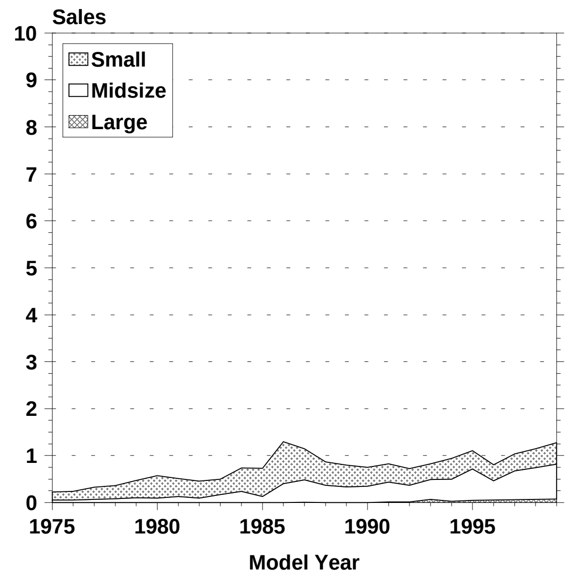

Figure 64

Significant change has occurred for imported trucks. Their sales fraction has changed from a mix of 75 percent small and 25 percent midsize in 1975, to about 36 percent small, 58 percent midsize, and 6 percent large in 1999.

Annual sales of small imported trucks increased from less than 200,000 in 1975 to almost 900,000 in 1986, but have not exceeded a half million in more than a decade. Conversely, annual sales of midsize imported trucks have increased relatively steadily, from 50,000 per year in 1975 and 1976 to over 100,000 in 1981, 500,000 in 1985, and nearly 750,000 this year. Large trucks have never accounted for more than 10 percent of the imported trucks, and while their sales are increasing, they have yet to reach the 100,000 per year level.

V. Trends by Vehicle Type and Size Class

Figure 1 showed that trucks are expected to account for over 45 percent of the light-duty vehicles produced during MY99. In Figures 65 and 66, cars and light trucks are classified into five vehicle types: cars (i.e. coupes, sedans, hatchbacks), (station) wagons, vans, sports utility vehicles (SUVs), and pickup trucks.

As shown in Table 7, large increases in market share have occurred for SUVs and vans at the expense of cars and wagons, with the market share for cars dropping from about 71 percent in 1975 to about 52 percent this year. Similarly, wagons have dropped from about 9.4 percent of the vehicles produced each year to a current value of less than 2 percent. The market shares for SUVs and vans have increased from about 2 to 20 and about 4 to 10 percent, respectively. By contrast, the market share of pickups has increased by 3 percent. The market share for MY99 SUVs is projected to exceed not only that of MY99 pickups and vans but also the *combined* market share of MY75 pickups, vans, and SUVs.

Table 7

Comparison of Sales Fraction of MY75 and MY99 Light-Duty Vehicles by Vehicle Type and Size

Vehicle	Sales Fractions		
Type	1975	1999	Change
Car	71.2%	51.8%	-19.4%
Wagon	9.4%	1.7%	-7.7%
Van	4.5%	10.3%	+5.8%
SUV	1.8%	19.9%	+18.1%
Pickup	13.1%	16.3%	+3.2%

Another way to compare sales fractions by vehicle type and size is to consider this data as a percentage of the total number of cars and trucks built each year. Table 8 and Figures 67 to 76 show the sales and sales fraction when the light-duty fleet is further divided into small, midsize, and large: cars, wagons, SUVs, vans, and pickups. Note that this classification method uses a total of fifteen vehicle-type/vehicle-size classes and that vehicles are not currently being produced for two of these classes, namely small vans and large wagons.

Sales Fraction by Vehicle Type

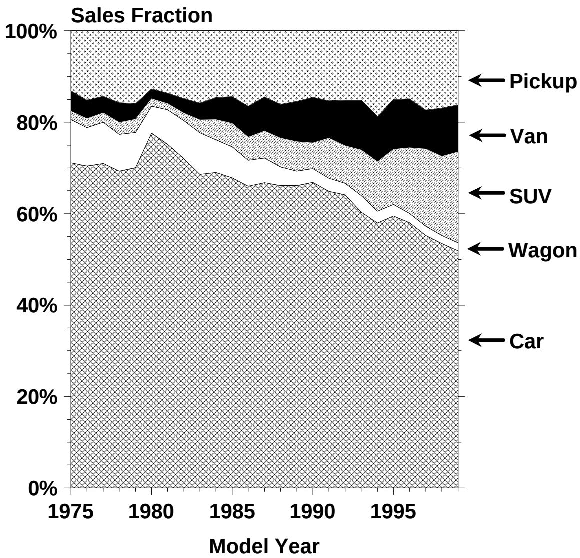

Figure 65

Sales by Vehicle Type

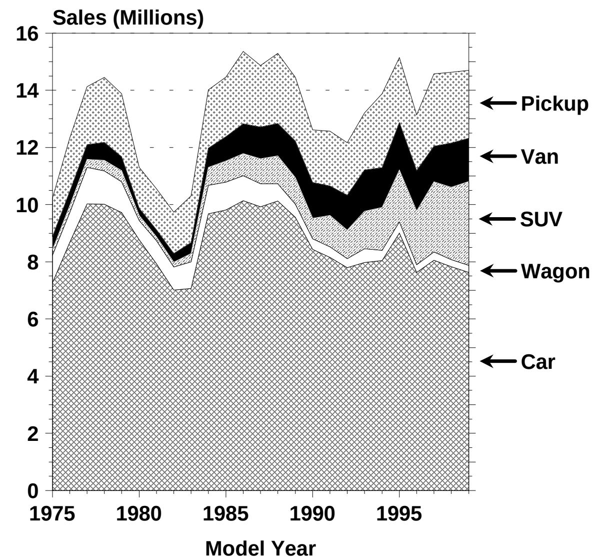

Figure 66

The largest increases in sales fraction on this basis have been for midsize SUVs and midsize vans. These two truck-size classes are expected to account for over 20 percent of the vehicles built this year, compared to a combined total in 1975 of about 4 percent. In 1975, large cars accounted for about 15 percent of total light-duty sales and ranked third. Their relative sales fraction is now about half of what it was then, and they now rank sixth. Midsize SUVs have taken over third place, and their relative sales fraction has increased by an order of magnitude from 1975 when they ranked eleventh.

In 1975, small cars accounted for 40 percent of all light-duty vehicles produced. While their sales fraction has remained the largest of the 15 vehicle sizes and types shown in Table 8, it has decreased to about 24 percent. Midsize cars have retained their number two ranking and have actually increased their sales fraction from 16 to 20 percent.

As indicated in Figure 67, the relative sales fractions of small, midsize, and large cars have been stable, particularly since 1980, and also when compared to the sales fractions of other vehicle types shown in Figures 69, 71, 73, and 75. Total

Table 8

Comparison of Sales Fraction of MY75 and MY99 Light-Duty Vehicles by Vehicle Type and Size

Vehicle Type	Vehicle Size	Sales Fractions 1975	1999	Change
Cars	Small	40.0%	23.6%	-16.4%
	Midsize	16.0%	20.2%	4.2%
	Large	15.2%	8.0%	-7.2%
Wagons	Small	4.7%	0.7%	-4.0%
	Midsize	2.8%	1.0%	-1.8%
	Large	1.9%	0.0%	-1.9%
Vans	Small	0.0%	0.0%	0.0%
	Midsize	3.0%	9.1%	6.1%
	Large	1.5%	1.2%	-0.3%
SUV	Small	0.5%	2.0%	1.5%
	Midsize	1.2%	11.7%	10.5%
	Large	0.1%	6.2%	6.1%
Pickup	Small	1.6%	1.6%	0.0%
	Midsize	0.5%	5.0%	4.5%
	Large	11.0%	9.7%	-1.3%

car sales (excluding wagons) have not exceeded 10 million vehicles per year in more than a decade. Currently, about 25 percent fewer cars are sold each year than in 1988. Most of this decline has come from small cars. In 1988 over 6.7 million small cars were sold, compared to 3.5 million this year.

Annual sales of midsize cars doubled between 1975 and 1978 when they increased from 1.6 million to over 3.3 million. Since then, they have not dropped below 2 million per year and for the past two years have been over 3 million per year. Annual sales of large cars peaked at 2.3 million in 1979 and have not been over 2 million per year since then. Since 1986, large cars sales have stayed in a relatively narrow range of 900 thousand to 1.3 million per year. Annual sales of wagons (see Figure 70) have not exceeded 1.5 million in 15 years, have been below 500 thousand per year for nearly a decade, and are more than 75 percent below what was achieved in the late 70's.

Car Sales Fraction by Vehicle Size

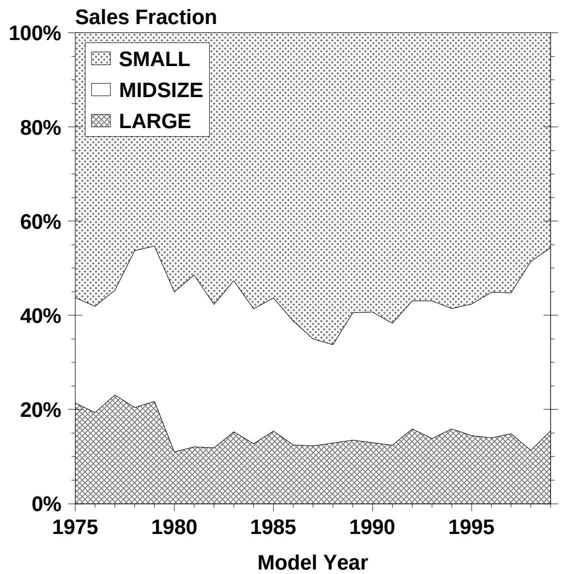

Figure 67

Car Sales by Vehicle Size

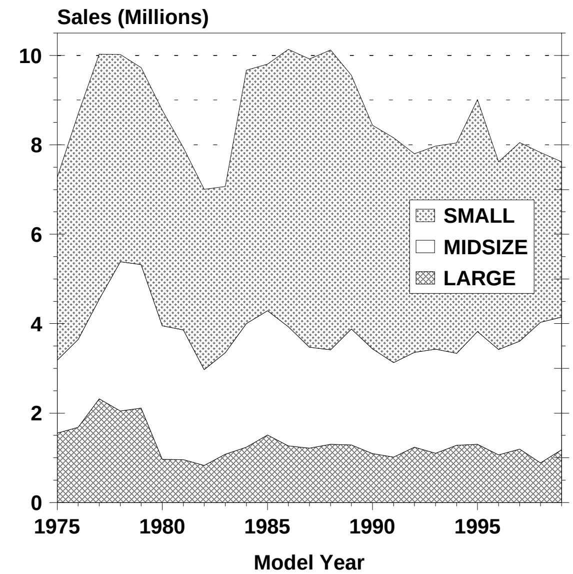

Figure 68

Wagon Sales Fraction by Vehicle Size

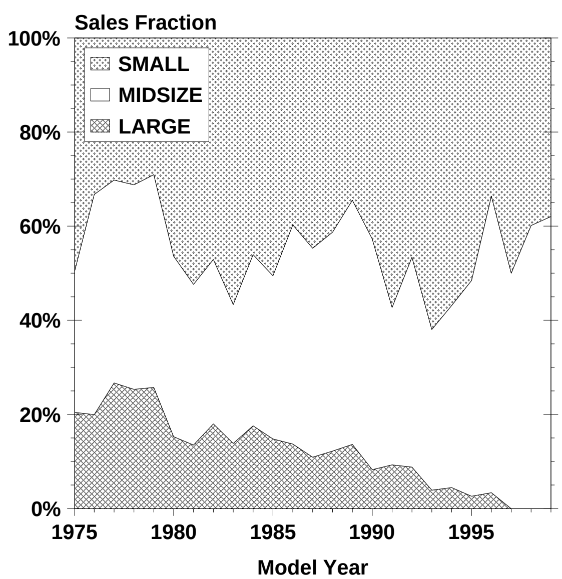

Figure 69

Wagon Sales by Vehicle Size

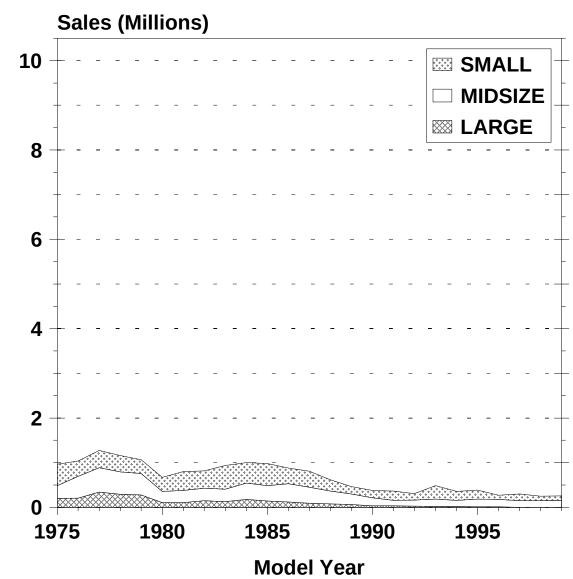

Figure 70

Van Sales Fraction by Vehicle Size

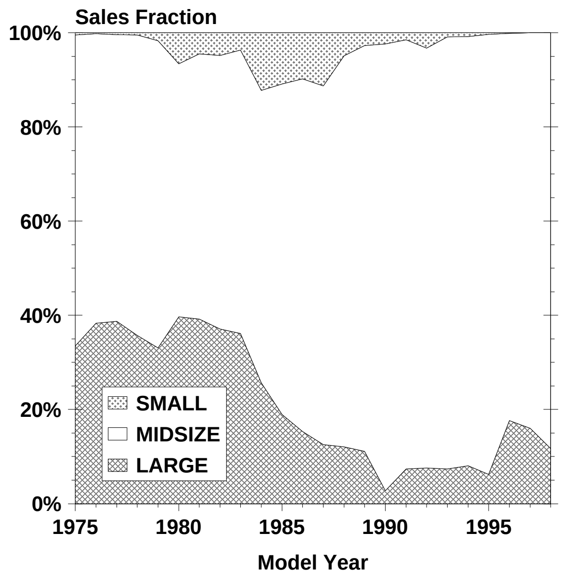

Figure 71

Van Sales by Vehicle Size

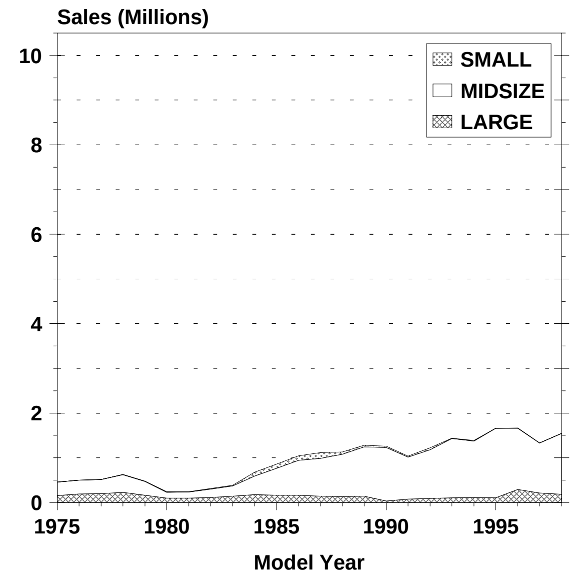

Figure 72

SUV Sales Fraction by Vehicle Size

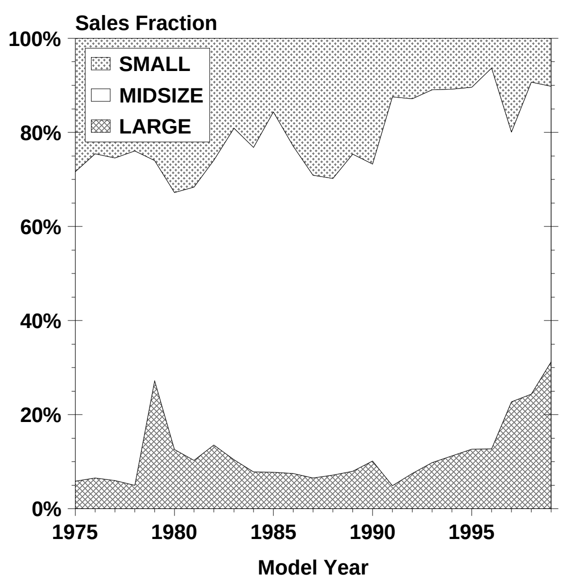

Figure 73

SUV Sales by Vehicle Size

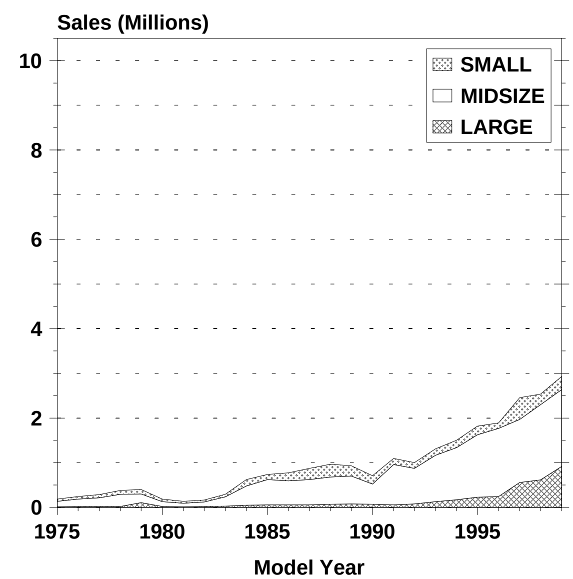

Figure 74

In 1975, approximately 8.2 million cars and wagons were produced, about the same as are projected to be produced this year (7.9 million). The 27-percent reduction in car and wagon sales fraction thus can be attributed to increasing sales of light trucks, particularly midsize vans and SUVs. In both cases, over a million more midsize SUVs and midsize vans are expected to be produced during MY99 than in MY75.

Between 1975 and 1986, annual sales of vans doubled from less than a half million per year to more than a million (see Figure 72). Since then, their sales have gone up by another half million vehicles per year and are now three times higher than they were in 1975 with almost all of this increase occurring in the midsize van segment. Sales of small vans, which are not currently being produced, have rarely exceeded 100,000 per year. Similarly, sales of large vans have stayed in a relatively narrow range of about 100,000 to 300,000 vehicles per year. For MY99, nearly 90 percent of all vans will be midsize.

From 1975 to 1983, sales of SUVs remained well below 500,000 per year. Since then, their sales have increased by a factor of more than 15, from less than 200,000 in 1975 to nearly 3 million this year. This increase has occurred in all three vehicle sizes shown in Figure 74 with small SUVs increasing from 50,000 to 300,000 vehicles per year, midsize SUVs increasing from 123,000 to 1.7 million per year, and large SUVs from 11,000 to about 900,000 per year.

As shown in Figure 73, the relative market share for large SUVs has increased from about 10 percent in 1975 to over 30 percent this year. Conversely, the relative share of small SUVs peaked at just over 30 percent in 1980 and 1981 and will be about 10 percent this year. On a percentage basis, midsize vehicles have always dominated this vehicle type.

Sales of pickups peaked at 2.6 million per year in 1994, about twice as many as were sold in 1975. Annual sales of small pickups have remained relatively stable, i.e., from about 250,000 to 500,000 and exceeded 500,000 only in 1986 when 743,000 were sold and dropped below 250,000 per year only in 1975 and 1976. Sales of midsize pickups remained below 100,000 per year through 1986, then increased to over a million in 1987 and 1988, and have remained between 600,000 and one million since then.

Annual sales for large pickups have also been relatively stable, increasing from 1.1 million in 1975 to nearly 2 million in 1978, then dropping to a nominal one million per year through 1993. For MY99, about 1.5 million large pickups will be sold.

Pickup Sales Fraction by Vehicle Size

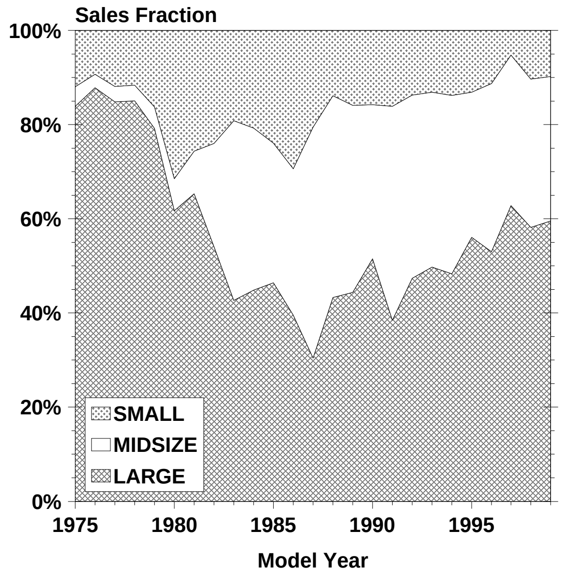

Figure 75

Pickup Sales by Vehicle Size

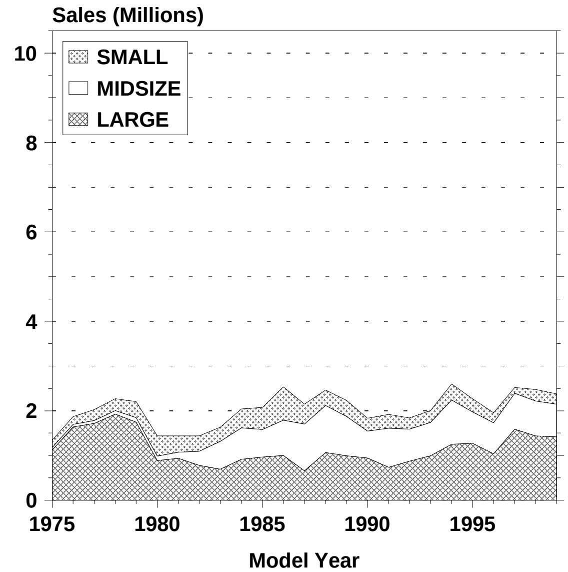

Figure 76

Table 9 compares the changes in fuel economy that have occurred by vehicle size and type. Average fuel economy for all vehicle size and type classes that are represented by MY99 vehicles is higher this year than it was in 1975. Four of these vehicle size/type classes have achieved double digit MPG increases; i.e., fuel economy of small cars, midsize cars, large cars, and midsize wagons has increased by ten or more MPG.

Fuel economy increases since 1975 for the nine truck vehicle size/types have all been less than 10 MPG with small and midsize pickups on both a percentage and absolute basis achieving the smallest improvement, namely about 2 MPG.

It should be noted that for MY99 large cars get higher fuel economy than all of the truck classes, with one minor exception, small pickups, which will achieve 24.5 MPG compared to 24.3. In addition, five of the truck size/type classes (midsize vans, small and midsize SUVs, and small and midsize pickups get higher MPG this year, than small, midsize, and large cars did in 1975. For example, midsize SUVs will achieve 20.8 MPG in 1999, compared to 18.3, 13.6, and 13.1 MPG for small, midsize, and large cars.

Table 9

Comparison of Fuel Economy of MY75 and MY99 Light-Duty Vehicles by Vehicle Type and Size

Vehicle Type	Vehicle Size	MPG 1975	MPG 1999	MPG Increase	Percent Increase
Cars	Small	18.3	30.6	12.3	67.2%
	Midsize	13.6	27.2	13.6	100.0%
	Large	13.1	24.3	11.2	85.5%
Wagons	Small	22.4	32.2	9.8	43.8%
	Midsize	13.2	26.1	12.9	97.7%
	Large	11.9	----	—--	----
Vans	Small	20.6	----	---	----
	Midsize	13.3	22.7	9.4	70.7%
	Large	12.6	17.8	5.2	41.3%
SUV	Small	16.1	24.8	8.7	54.0%
	Midsize	12.1	20.8	8.7	71.9%
	Large	12.2	16.7	4.5	36.9%
Pickup	Small	22.5	24.5	2.0	8.9%
	Midsize	21.1	23.4	2.3	10.9%
	Large	13.1	18.3	5.2	39.7%

Figure 2 shows that, on a model year basis, estimated lifetime fuel consumption for light trucks has been higher than that of cars for the past five years. Table 10 makes a similar estimate of lifetime fuel consumption for the 15 vehicle type/size classes. Cars and wagons built in MY75 accounted for about 80 percent of that model year's vehicle life fuel consumption, with large pickups accounting for another 15 percent.

As relative sales fractions changed and vehicle fuel economy improved, changes in vehicle lifetime fuel consumption have occurred. Lifetime fuel consumption has decreased for all of the car and wagon size classes, and significant increases have occurred for midsize vans, midsize and large SUVs, and large pickups. These three classes now account for 30 percent of the lifetime fuel consumption compared to about 6 percent in 1975.

Table 10

Estimated Relative Vehicle Lifetime Fuel Consumption of MY75 and MY99 Light-Duty Vehicles by Vehicle Type/Size

Vehicle Type	Vehicle Size	Percent of Fuel Consumed 1975	Percent of Fuel Consumed 1998	Change
Cars	Small	31.5%	16.6%	-14.9%
	Midsize	17.0%	15.9%	-1.1%
	Large	16.8%	7.1%	-9.7%
Wagons	Small	3.6%	0.5%	-3.1%
	Midsize	3.7%	1.1%	-2.6%
	Large	2.8%	----	-2.8%
Vans	Small	----	----	-----
	Midsize	3.9%	10.4%	6.5%
	Large	2.1%	1.7%	-0.4%
SUV	Small	0.6%	2.1%	1.6%
	Midsize	1.7%	14.5%	12.7%
	Large	0.2%	9.6%	9.4%
Pickup	Small	1.2%	1.7%	0.5%
	Midsize	0.5%	5.5%	5.0%
	Large	14.6%	13.5%	-1.1%

Figures 3, 4, and 6 compared MPG, inertia weight, 0 to 60 time, and ton-MPG for passenger cars and light trucks. Figures 77 to 96 make similar comparisons by vehicle size and type.

At this level of stratification, the trends observed earlier for passenger cars for inertia weight, MPG, and 0 to 60 time repeat. In the late 1970's, increases in MPG for these vehicles were accompanied by decreases in inertia weight and relatively constant 0 to 60 times. Since then, for all six car and wagon sizes shown in Figures 77 to 84, MPG has been relatively stagnant, but increases in inertia weight and decreases in 0 to 60 time have occurred. Small, midsize, and large cars can not be readily distinguished by their ton-MPG trend which has increased at a relatively consistent rate for cars. The same can be said of small and midsize wagons, but large wagons, which have not been produced since 1996, achieved significantly higher ton-MPG than their smaller counterparts between 1980 and 1996.

MPG and Performance
Small Cars

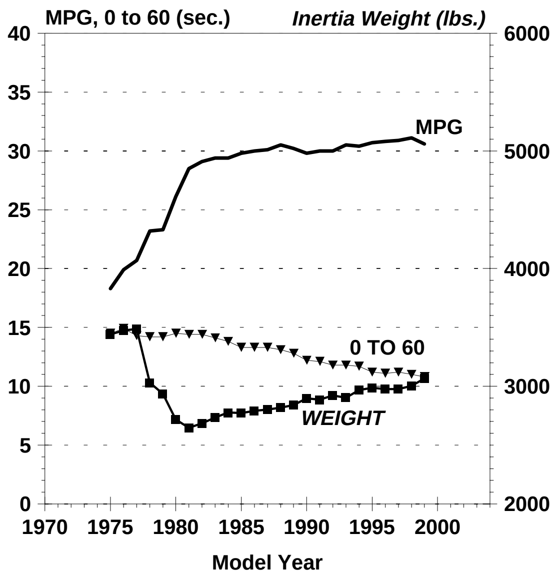

Figure 77

MPG and Performance
Midsize Cars

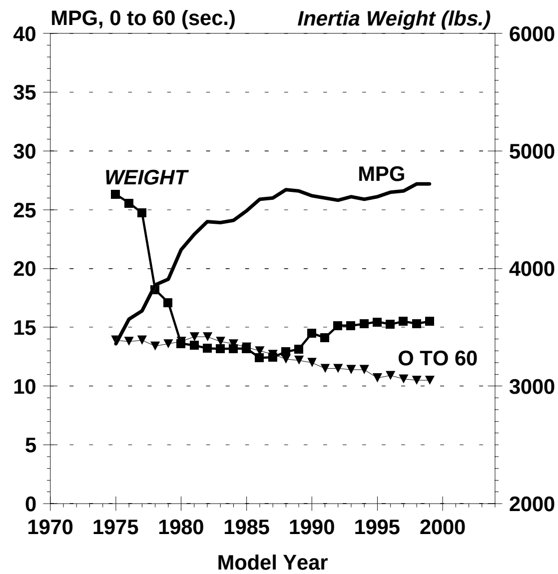

Figure 78

MPG and Performance
Large Cars

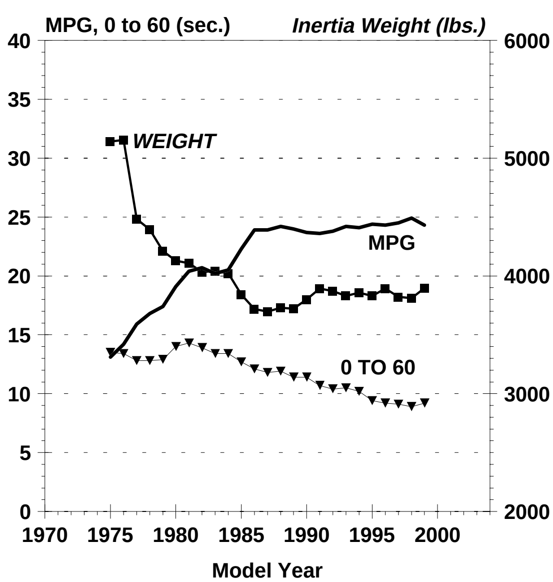

Figure 79

Ton-MPG
Cars

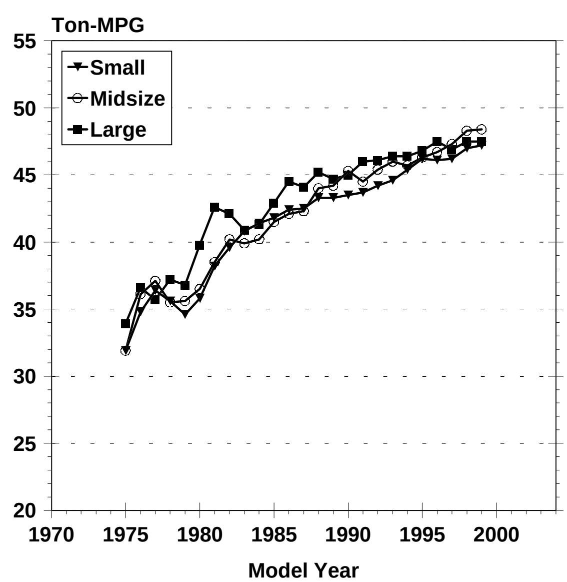

Figure 80

MPG and Performance
Small Wagons

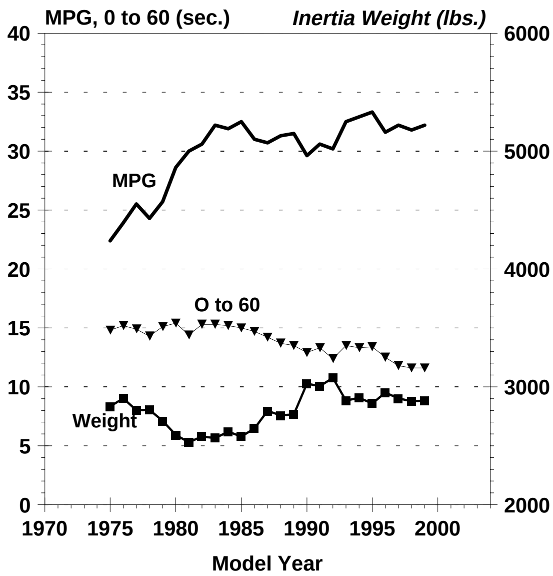

Figure 81

MPG and Performance
Midsize Wagons

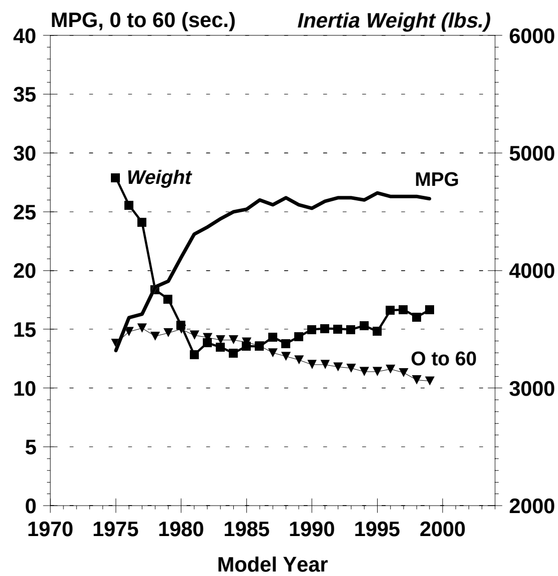

Figure 82

MPG and Performance
Large Wagons

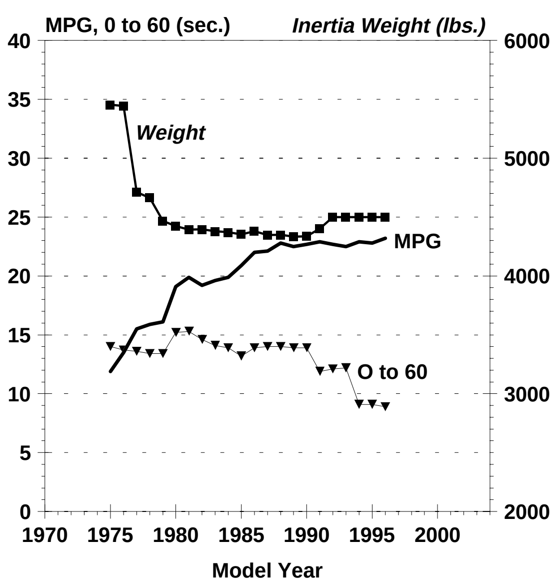

Figure 83

Ton-MPG
Wagons

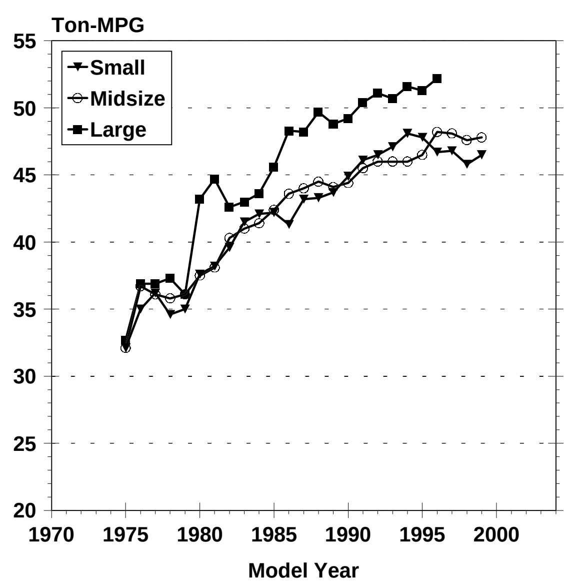

Figure 84

As shown in Figure 85, MPG for small vans increased over 25 percent between 1975 and 1996, the latest year in which any were built. During this time their weight remained relatively stable, but their 0 to 60 time dropped 7 seconds. Similarly, fuel economy for midsize vans (see Figure 86) increased by 6.5 MPG between 1975 and 1985 but less than 3 MPG since then. Their inertia weight dropped nearly 300 pounds between 1975 and 1985 but is now higher than it was in 1975. Estimated 0 to 60 time for this vehicle size/type remained at about 14 to 15 seconds through 1986 but has declined since then. Large vans show an increasing trend in inertia weight and are now over 1000 pounds heavier than they were in 1975. Their fuel economy increased from 12.6 MPG in 1975 to 16.8 in 1981 and has remained relatively constant for 17 years. Ton-MPG for all three sizes of vans has improved consistently (Figure 88).

Inertia weight for small SUVs has ranged from a low of about 2800 pounds in 1983 to a high of about 3500 pounds this year and also in 1997. Fuel economy for small SUVs peaked at 28.5 in 1996 when their weight dropped below 2900 pounds. Estimated 0 to 60 time for this class of vehicles increased to over 15 seconds in 1986 and has since dropped to 11.7 seconds. Between 1975 and 1985, midsize SUV weight decreased by over 700 pounds, their 0 to 60 time remained relatively constant, and their fuel economy improved from 12.1 to 19.7 MPG. Since 1985, their weight has gone up by about 200 pounds, their 0 to 60 time decreased by over 3 seconds, and their fuel economy has remained at 20 to 21 MPG.

Fuel economy for large SUVs increased from 12.2 MPG in 1975 to 18.9 MPG in 1982 when over half of them had diesel engines, their ton-MPG peaked at 52.7, and their 0 to 60 time exceeded 16 seconds. Since then, use of diesel engines in this vehicle class has declined substantially. For the past fifteen years, fuel economy for large SUVs has remained at about 16 or 17 MPG, but their inertia weight increased from 4728 pounds in 1975 to 5260 in 1979, and over 5500 this year. Large SUV inertia weight has not been below 5000 pounds in two decades.

Use of diesel engines also accounts for much of the MPG improvement of small pickups between 1981 and 1982 when they peaked at 28.2 MPG in 1981 when over 22 percent had diesel engines and had an average 0 to 60 time of about 15 seconds. Since 1975, inertia weight for small pickups has increased by over 700 pounds; it has not been below 3000 pounds since 1984. Inertia weight for midsize pickups remained at about 3000 pounds between 1975 and 1986 but has increased by 700 pounds since then. Their 0 to 60 time has dropped from over 17 to 18 seconds in the late 1970's to about 12 seconds in 1994 where it remains. In the last decade midsize pickup fuel economy has decreased by over 2 MPG.

MPG and Performance
Small Vans

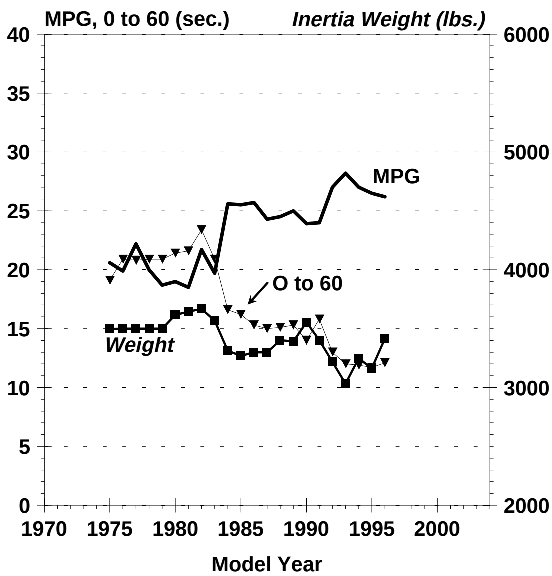

Figure 85

MPG and Performance
Midsize Vans

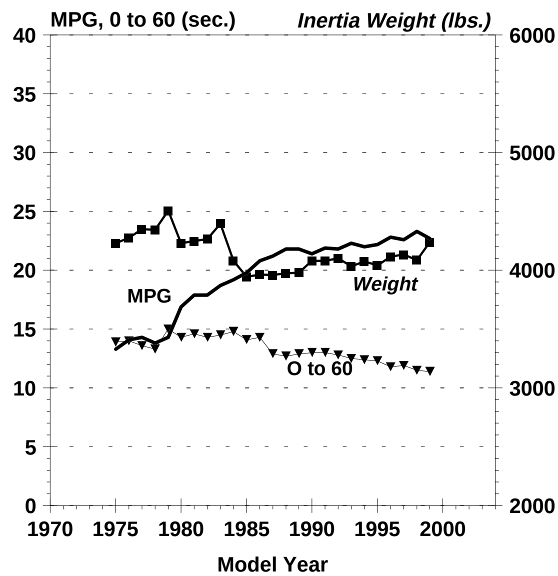

Figure 86

MPG and Performance
Large Vans

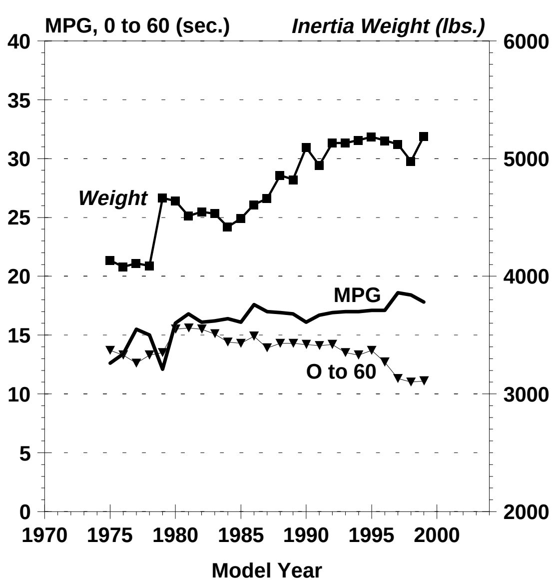

Figure 87

Ton-MPG
Vans

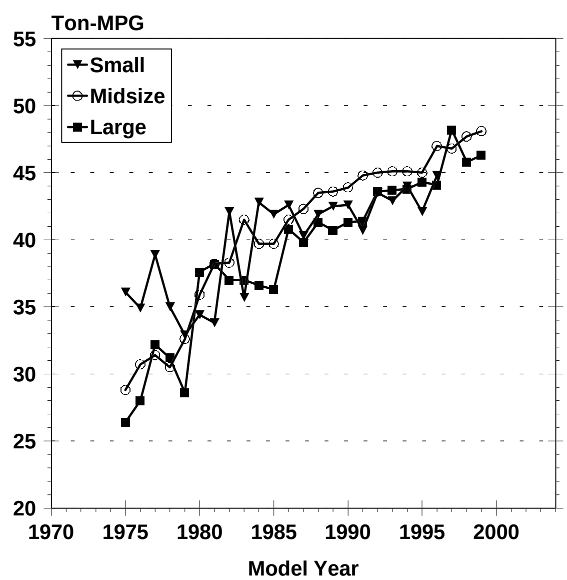

Figure 88

MPG and Performance
Small SUVs

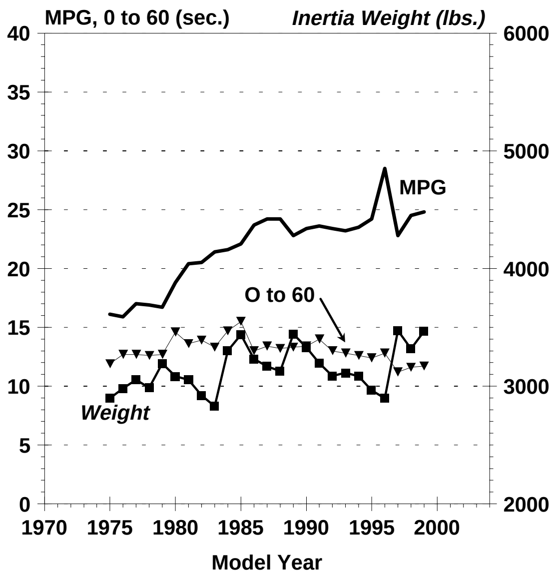

Figure 89

MPG and Performance
Midsize SUVs

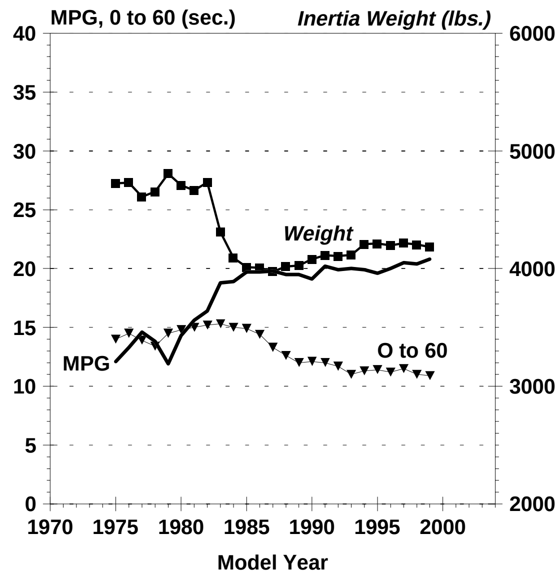

Figure 90

MPG and Performance
Large SUVs

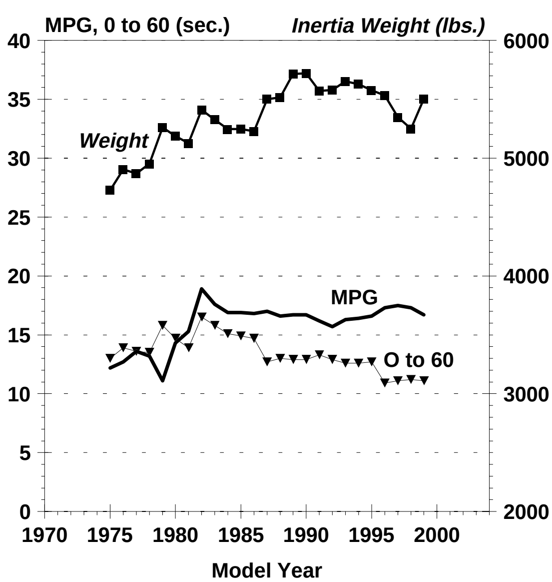

Figure 91

Ton-MPG
SUVs

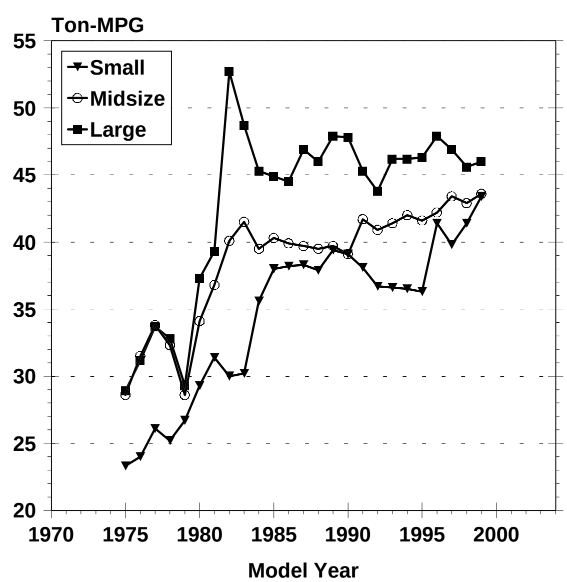

Figure 92

MPG and Performance
Small Pickups

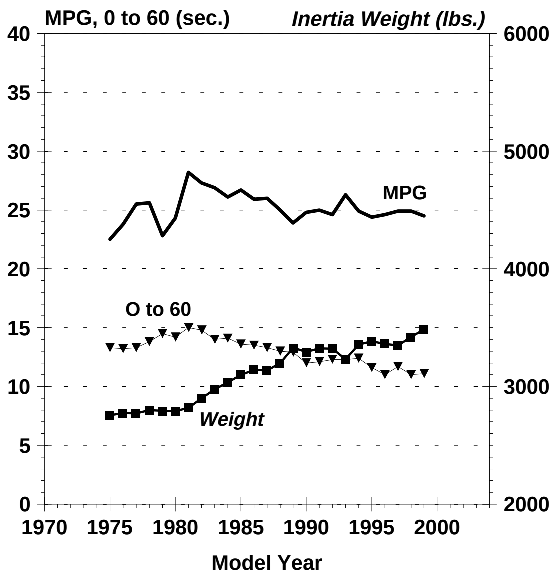

Figure 93

MPG and Performance
Midsize Pickups

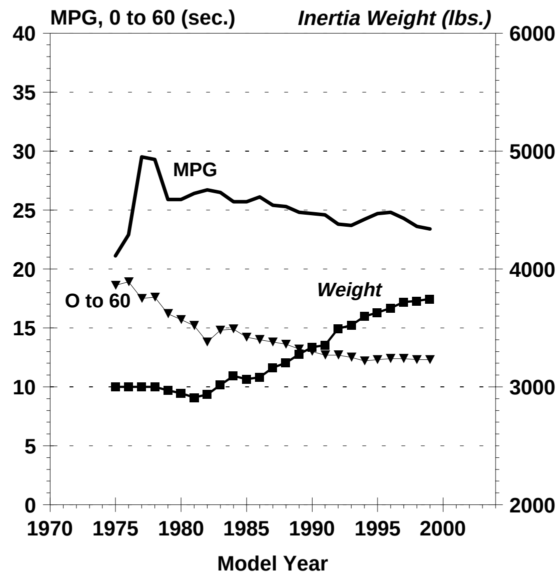

Figure 94

MPG and Performance
Large Pickups

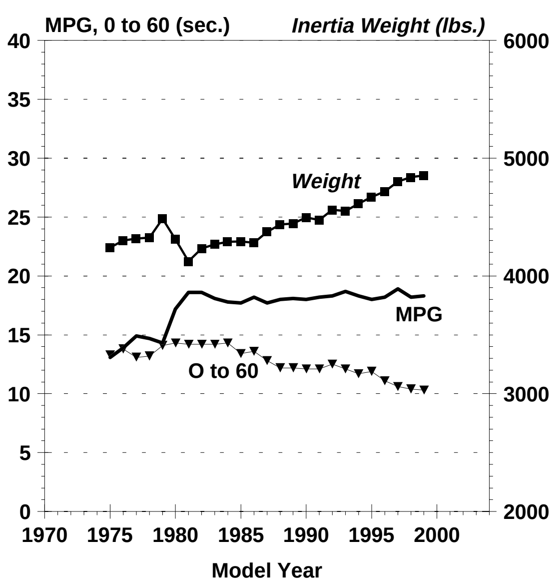

Figure 95

Ton-MPG
Pickups

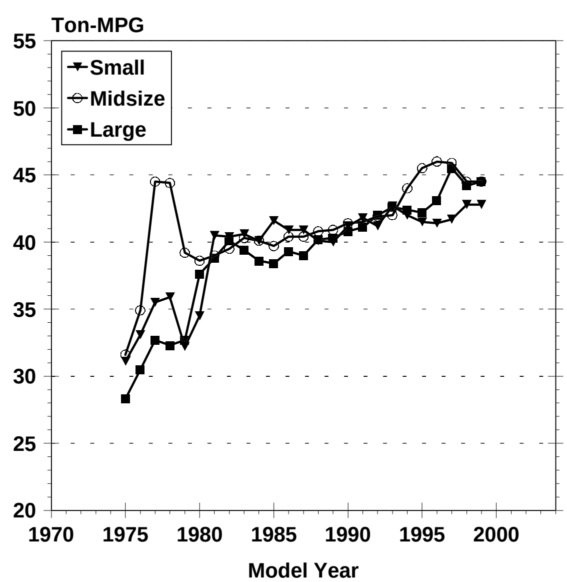

Figure 96

Large pickups show a trend toward increasing weight, decreasing 0 to 60 time, and relatively constant fuel economy of about 18 to 19 MPG since 1981, compared to 13.1 MPG in 1975.

Table 11 compares technology usage by vehicle type and size. Front-wheel drive dominates the car and wagon size classes shown except for midsize wagons which are only 40-percent front-wheel drive. Five out of six midsize vans now use front-wheel drive, but none of the large vans do. Four-wheel drive is used heavily in SUVs, pickups, and wagons, but very little use of it is made in vans and cars.

Large vehicles make greater use of automatic/lockup transmissions than their midsize or small counterparts. The opposite holds for usage of four-valve engines with small and midsize vehicles making greater use of this technology than large ones. Domestic vehicles dominate all the midsize and large vehicle types except midsize wagons; imports dominate all of the small vehicles except small wagons.

Table 11

MY99 Technology Usage by Vehicle Type and Size (Percent of Vehicle Type/Size Strata)

		Vehicle Type				
Technology	**Size**	**Cars**	**Wagons**	**Vans**	**SUVs**	**Pickups**
Front-Wheel Drive	Small	85.2	81.2	---	9.2	0.0
	Midsize	94.1	40.7	83.3	1.7	0.0
	Large	65.7	---	0.5	0.0	0.0
Four-Wheel Drive	Small	1.4	14.1	---	74.5	39.6
	Midsize	1.5	57.1	4.5	71.2	23.7
	Large	0.0	---	0.0	76.3	51.4
Manual Transmission	Small	26.1	26.1	---	42.9	67.6
	Midsize	4.3	14.3	0.0	6.1	50.7
	Large	0.0	---	0.0	0.0	8.7
Four Valves per Cylinder	Small	65.8	44.2	---	75.6	92.9
	Midsize	60.8	72.1	11.9	25.3	0.0
	Large	42.7	---	0.0	3.6	0.0
Domestic	Small	45.9	67.4	---	24.4	0.0
	Midsize	50.0	28.8	86.1	67.7	100.0
	Large	92.7	---	99.5	91.7	100.0

VI. Fuel Economy Improvement Potential

In references 20 and 24, MPG capability contained in the then current fleet was examined using a method called the "best-in-class" (BIC) analysis. In a BIC analysis, one divides the baseline fleet of vehicles into classes and then examines the MPG characteristics of each class. If one selects the MPG performance of the best cars in the class (hence the name), one can recompute a fleet average using the best cars' MPG and the same relative sales proportions of the fleet that existed in the baseline. This analysis technique was one of the methods used to investigate future fleet MPG capability when the original fuel economy standards were set.

The classes may be generated in any way, but the most common classes are those that are based on the car classes used for the EPA/DOE Gas Mileage Guide and the inertia weight classes used for EPA's emission certification program. We have chosen to use inertia weight classes, since if the sales proportions in each inertia weight class are held constant, the average weight of the fleet does not change. The MPG values of the best “dozen” vehicles in each class were averaged, and the resulting values were used to re-calculate the fleet MPG values using the same relative proportions in each of the weight classes that constitute the fleet.

Appendix C gives a listing of the MY99 vehicles used in the BIC analysis. It should be noted that some of the weight classes have less than a dozen representative vehicles. In addition, for cases where technically identical vehicles with different nameplates are used, such as the Oldsmobile 88/Buick LeSabre, the Plymouth Voyager/Dodge Caravan, or Geo Tracker/Suzuki Sidekick, only one representative vehicle was included.

The results of the analysis are summarized in Table 12, which shows almost a 13-percent increase in MPG for cars and a 9-percent increase for light trucks. The vehicles used for the BIC analysis have less powerful engines and are more likely to be equipped with manual transmissions, compared to the fleet as a whole. Usage of front- and four-wheel drive is about the same for cars in the BIC data set as in the entire fleet. For trucks, however, the BIC data set vehicles make less use of four-wheel drive and greater use of front-wheel drive (33 percent vs. 47 percent and 33 percent vs. 17 percent, respectively).

Despite the fact that over 60 percent of the cars in the BIC data set are classified as “Small” compared to 45 percent in the entire fleet, average interior volume for cars in the BIC analysis is only slightly smaller than the overall average (109 vs. 103 cu. ft). In addition, the percentage of trucks that are classified as “Small”, “Midsize,” and “Large” is about the same for the two cases studied.

If the BIC MPG values for passenger cars and trucks are used to compute a total fleet MPG value, the result is 26.4 MPG compared to the actual 23.8 value found in Table 1, roughly an 11-percent increase.

Table 12

Best-in-Class (BIC) Results Model Year 1999				
	Passenger Cars		**Light Trucks**	
	BIC	**Average**	**BIC**	**Average**
55/45 MPG	31.7	28.1	22.1	20.3
Weight	3382	3382	4433	4433
Volume	103	109	---	---
CID	136	169	217	249
HP	154	166	184	190
0-60 Time	11.0	10.5	11.8	11.1
% FWD	88	85	33	17
% Four Wheel Drive	3	3	33	47
% Manual Trans.	60	14	22	13
% Four Valve	73	60	36	16
% Small	61	45	11	8
% Midsize	37	40	58	56
% Large	2	15	31	37
% Domestic	16	54	63	81

VII. Conclusions

1. Fuel economy of the overall light-duty fleet has declined 2.1 MPG (i.e., about eight percent) since reaching a maximum of 25.9 MPG in 1987 and is now the lowest it has been in nineteen years, although during the past decade fuel economy of both cars and light-duty trucks has been relatively stable.

2. Ton-MPG, for the combined fleet, as a measure of efficiency, has increased each year for the past 20 consecutive years.

3. The share of the market comprised by light trucks has been increasing for over 20 years and now exceeds 45 percent, more than double what it was in 1979. Much of this increase can be attributed to the increase in the sales fractions of midsize vans and SUVs.

4. On a model year basis, estimated lifetime light-truck fuel consumption has exceeded that of passenger cars for the past five years; for model year 1999, light trucks are projected to consume 59 percent of the total.

5. Both cars and light trucks have traded off fuel economy for increased weight and performance. Since 1986, vehicle inertia weight for cars and trucks has increased by eleven and nineteen percent, respectively. During the same time period, vehicle performance, as determined from estimated 0 to 60 acceleration time, has also improved. Had model year 1999 cars and light trucks had 13.2 second estimated 0 to 60 time and the same weight as they did in 1986, they would have been able to achieve five MPG more than they did.

6. Using a Best-in-Class methodology, the combined passenger car and light-truck fleet has the potential to attain at least 26.4 MPG -– eleven percent greater than the current value.

VIII. Acknowledgments

The authors wish to express their thanks and sincere appreciation to those who reviewed this report and to Lillian Johnson for word processing, editing, and report preparation. The authors would also like to take this opportunity to acknowledge the efforts and work of the team of EPA's Office of Mobile Sources, Vehicle Programs and Compliance Division (VPCD) programmers and analysts who designed, developed, and implemented the new Certification and Fuel Economy Information System (CFEIS). Without the efforts of Kassem Abbas, Steve Bliss, Ann Chiu, Karen Danzeisen, Dan Harrison, John Hendon, Seung Park, and Richard Parsons, the data base used in this report could not have been updated with Model Year 1996 and 1997 Final CAFÉ and Model Year 1998 and 1999 General Label data. Special thanks also go to the late Rick Zellin who did much of the CFEIS design work.

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